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Final

Environmental Impact Statement

for a

Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Readers Guide
and
Summary

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250

February 2002

ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the U.S. Department of Energy (DOE) limited the use of acronyms and abbreviations in this environmental impact statement. In addition, acronyms and abbreviations are defined the first time they are used in each chapter or appendix. The acronyms and abbreviations used in the text of this document are listed below. Acronyms and abbreviations used in tables and figures because of space limitations are listed in footnotes to the tables and figures.

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
LCF	latent cancer fatality
MTHM	metric tons of heavy metal
NEPA	National Environmental Policy Act, as amended
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act, as amended
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
REMI	Regional Economic Models, Inc.
RMEI	reasonably maximally exposed individual
Stat.	United States Statutes
TSPA	Total System Performance Assessment
U.S.C.	United States Code

UNDERSTANDING SCIENTIFIC NOTATION

DOE has used scientific notation in this EIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number between 1 and 10 and a positive or negative power of 10. Examples include the following:

Positive Powers of 10
$10^1 = 10 \times 1 = 10$
$10^2 = 10 \times 10 = 100$
and so on, therefore,
$10^6 = 1,000,000$ (or 1 million)

Negative Powers of 10
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/100 = 0.01$
and so on, therefore,
$10^{-6} = 0.000001$ (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are three chances in 1,000,000 that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.

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Readers Guide

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WHY A READERS GUIDE?

The Proposed Action for this environmental impact statement (EIS) – to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain in Nevada – is complex. The EIS evaluates not only impacts associated with constructing, operating, and closing a repository, but also those associated with transporting the materials to the Yucca Mountain Repository site. In addition to evaluating the near-term impacts of those activities, the EIS evaluates impacts that could occur hundreds of thousands of years in the future.

The No-Action Alternative is also complex, involving estimated impacts of allowing spent nuclear fuel and high-level radioactive waste to remain at 72 commercial and 5 U.S. Department of Energy (DOE, or the Department) sites across the United States.

In addition to the Draft EIS, DOE issued a Supplement to the Draft EIS. The Department received thousands of comments on the Draft EIS and the Supplement, and considered each comment in preparing the Final EIS. DOE has prepared this guide to help the reader understand the Final EIS, its different parts, and the approach the Department followed in moving from Draft EIS to Final EIS.

WHY DID DOE CHANGE THE EIS?

The Proposed Action for this EIS has not changed. With that in mind, and in accordance with Council on Environmental Quality regulations under the National Environmental Policy Act of 1969, as amended, DOE relied on three criteria for introducing changes to information presented in the Draft EIS and the Supplement to the Draft EIS in the preparation of this Final EIS. The Department changed the EIS (1) in response to public comments as appropriate, (2) to correct errors in the Draft EIS or the Supplement to the Draft EIS, and (3) to provide new information or improved analyses relevant to the EIS. For example, DOE changed the EIS to identify its preferred transportation mode (mostly rail nationally and in Nevada), to incorporate 2000 Census data, to address the final Environmental Protection Agency standards and Nuclear Regulatory Commission rule related to Yucca Mountain, and to add Appendix M to provide general transportation information not specifically related to the transportation analysis considered in Chapter 6 and Appendix J.

DOE issued the Draft EIS in August 1999 and requested comments on it. The Department received more than 11,000 comments in letters, e-mails, faxes, and transcripts of public hearings at 21 locations across the country. As described below, Volume III of this EIS contains all of those comments individually or in summary form, and the DOE responses to them. Some of those comments led DOE to change or update the EIS, primarily to enhance understanding, but also to correct errors that readers found.

In addition to errors pointed out by the public during the comment periods on the Draft EIS and the Supplement to the Draft EIS, DOE internal reviewers found typographical or editorial errors. These errors have been corrected in the Final EIS.

Finally, DOE has included new information and related analyses in the Final EIS. The primary example concerns the evolving nature of the repository design. In May 2001, DOE issued for public comment the Supplement to the Draft EIS to address the repository design evolution. This Final EIS incorporates the design information from the Supplement and, in some cases, updates that information. These changes occur throughout the EIS, but primarily in Chapters 2, 4, and 5. DOE made other changes to the EIS in response to the more than 1,900 public comments it received on the Supplement.

HOW DID DOE CHANGE THE EIS?

This Final EIS is based on the Draft EIS and the Supplement to the Draft EIS. Although not required by regulations, DOE has chosen to indicate substantive changes (additions and deletions) to the scientific and technical analyses of impacts with "change bars" in the margins of the affected pages. These change bars indicate new or revised information acquired since the publication of the Draft EIS or the Supplement, information based on revised analyses, and information included as the result of public comments. DOE did not use change bars for editorial changes (including references) or rephrased (but technically unchanged) information from the Draft EIS or the Supplement to the Draft EIS.

As mentioned above, changes and updates to the EIS came about for a variety of reasons. The primary reason was the evolving nature of the repository design, which was the basis for the preparation of the Supplement to the Draft EIS. This Final EIS incorporates new analyses based on the flexible design higher- and lower-temperature repository operating modes introduced in the Supplement and now described in Chapter 2 and the resultant environmental impacts, as described in Chapters 4 (preclosure impacts) and 5 (postclosure impacts). The design evolution also affected the analyses described in Chapter 8 (cumulative impacts) and Chapter 6 (transportation impacts related to shipments of additional repository components and construction materials).

A number of commenters on the Draft EIS or on the Supplement to the Draft EIS requested DOE to make changes, and DOE did so where appropriate. However, some suggested changes were inappropriate because they would have introduced errors or because they were not germane to the Proposed Action. Other than the three types of changes described above, the Department did not alter the EIS.

The following list highlights areas of change incorporated in this Final EIS:

- More information regarding potential impacts, particularly impacts associated with transportation of spent nuclear fuel and high-level radioactive waste within Nevada
- Use of a "representative" fuel assembly in the accident analysis
- Use of updated data, particularly population data in the impact analyses
- A more detailed discussion of the issue of potential impacts associated with negative perceptions about the repository project
- Use of updated versions of computer models for assessing human health and transportation impacts
- Corrections or editorial changes for accuracy and clarity
- Addition of an appendix that contains general information about transportation of radioactive materials not specifically used in the analysis, but provided for public information
- Addition of the U.S. Fish and Wildlife Service Biological Opinion as an appendix to the Final EIS
- Addition of a Readers Guide to help readers understand the Final EIS

Readers will notice a change in the way this Final EIS presents references. In the Draft EIS, a reference appeared in the form, for example, DOE 1998a, p. 5. In the Final EIS, the same reference appears as DIRS 101779-DOE 1998, p. 5. Because of the large number of references cited in the Final EIS, DOE has introduced the Document Input Reference System (DIRS) to ensure that each citation is appropriate and proper. In addition, to aid the reader, DOE decided to put the reference list for each chapter at the end of that chapter and to not use a single list (which appeared in the Draft EIS as Chapter 12).

WHAT DOES THE FINAL EIS LOOK LIKE?

This *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* has four parts:

- Readers Guide and Summary
- Volume I – Impact Analyses, Chapters 1 through 15
- Volume II – Appendixes A through O
- Volume III – Comment-Response Document
- Volume IV – Additional information available upon written request to the DOE EIS Document Manager.

The purpose of the Summary is to present a condensed discussion of the analyses and impacts related to the Proposed Action and the No-Action Alternative, derived from the descriptions in Volumes I and II and from comments and responses contained in Volume III. The Summary stresses the major conclusions, areas of controversy, and issues to be resolved.

In developing the outline for Volume I, DOE adapted the EIS outline suggested by the Council on Environmental Quality (see 40 CFR 1502.10). The EIS outline is as follows:

Chapter 1 – Purpose and Need for Agency Action – establishes the need for DOE to take action.

Chapter 2 – Proposed Action and No-Action Alternative – describes what DOE proposes to do and the alternative of not building and operating a repository at Yucca Mountain.

Chapter 3 – Affected Environment – presents information on the 13 resource areas that the Proposed Action could affect at Yucca Mountain and along potential transportation routes, and on the affected environment of commercial and DOE sites to provide an analytical basis for the No-Action Alternative.

Chapter 4 – Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure – describes potential impacts of the Proposed Action described in Chapter 2 on the Yucca Mountain environment described in Chapter 3. Chapter 4 also describes potential impacts of the offsite manufacturing of components that DOE would use in the repository.

Chapter 5 – Environmental Consequences of Long-Term Repository Performance – describes potential impacts of the Proposed Action described in Chapter 2 on the Yucca Mountain environment described in Chapter 3 after repository closure.

Chapter 6 – Environmental Impacts of Transportation – describes potential impacts of transportation activities nationally and in Nevada, as described in Chapter 2, on the transportation-related affected environment described in Chapter 3.

Chapter 7 – Environmental Impacts of the No-Action Alternative – describes potential impacts of the No-Action Alternative described in Chapter 2.

Chapter 8 – Cumulative Impacts – describes potential impacts of the Proposed Action described in Chapter 2 in combination with the impacts of other past, present, and reasonably foreseeable future actions.

Chapter 9 – Management Actions to Mitigate Potential Adverse Environmental Impacts – describes actions DOE could take to lessen the potential impacts described in Chapters 4, 5, 6, and 8.

Chapter 10 – Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible and Irretrievable Commitment of Resources – describes impacts that would remain after the application of the mitigation measures described in Chapter 9.

Chapter 11 – Statutory and Other Applicable Requirements – discusses the regulatory and other guidelines for which DOE would be responsible in implementing the Proposed Action.

Chapter 12 – References – **To facilitate ease of use of this Final EIS, DOE has removed this chapter and placed a list of references at the end of each of Chapters 1 through 11. Information regarding the availability of these references can be found in the DOE Reading Rooms (as listed in Appendix D) or on the internet at the Yucca Mountain Project website at *http://www.ymp.gov*.**

Chapter 13 – List of Preparers, Contributors, and Reviewers – lists the persons involved in the preparation of the Final EIS.

Chapter 14 – Glossary – contains definitions of terms used in the Final EIS. Words or phrases defined in the glossary are italicized the first time they are used in the text.

Chapter 15 – Index.

Volume II contains a number of appendixes related to the Proposed Action and the No-Action Alternative, as follows:

Appendix A – Inventory and Characteristics of Spent Nuclear Fuel and High-Level Radioactive Waste and Other Materials – describes the inventory and characteristics of the spent nuclear fuel, high-level radioactive waste, and other highly radioactive material that DOE could dispose of at Yucca Mountain.

Appendix B – *Federal Register* Notices – contains notices published in the *Federal Register* regarding DOE's intent to prepare an EIS, EIS availability, and other matters related to this Proposed Action.

Appendix C – Interagency and Intergovernmental Interactions – describes consultations and other interactions between DOE and other agencies in relation to the Proposed Action.

Appendix D – Distribution List – includes the persons or organizations listed in the EIS distribution database at the time of publication of this Final EIS.

Appendix E – Environmental Considerations for Alternative Design Concepts and Design Features for the Proposed Monitored Geologic Repository at Yucca Mountain, Nevada – discusses features of the repository design as documented in Chapter 2.

Appendix F – Human Health Impacts Primer and Details for Estimating Health Impacts to Workers from Yucca Mountain Repository Operations – provides the basis for the information in Chapters 4 and 8 on human health impacts resulting from the Proposed Action.

Appendix G – Air Quality – provides the basis for the estimates in Chapters 4 and 8 of air quality impacts that would result from the Proposed Action.

Appendix H – Potential Repository Accident Scenarios: Analytical Methods and Results – provides the basis for potential impacts from the accident scenarios analyzed in Chapters 4, 5, 6, and 8.

Appendix I – Environmental Consequences of Long-Term Repository Performance – provides the basis for the potential impacts discussed in Chapter 5.

Appendix J – Transportation – provides the basis for potential impacts related to national and Nevada transportation, as discussed in Chapter 6.

Appendix K – Long-Term Radiological Impact Analysis for the No-Action Alternative – provides the basis for the potential impacts described in Chapter 7.

Appendix L – Floodplain/Wetlands Assessment for the Proposed Yucca Mountain Geologic Repository – describes floodplains near the Yucca Mountain site and along candidate transportation corridors and routes in Nevada.

Appendix M – Transportation Supplemental Information – In response to public comments, this new appendix provides general information not specifically related to the transportation analysis considered in Chapter 6 and Appendix J.

Appendix N – Are Fear and Stigmatization Likely, and How Do They Matter – In response to public comments, this new appendix addresses perceived risk and stigma, as discussed in Section 2.5.4.

Appendix O – Final Biological Opinion for the Effects of Construction, Operation and Monitoring, and Closure of a Geologic Repository at Yucca Mountain, Nye County, Nevada – This new appendix contains the text of the Biological Opinion issued by the U.S. Fish and Wildlife Service.

Volume III, the Comment-Response Document, contains the comments that DOE received on the Draft EIS and on the Supplement to the Draft EIS and the DOE responses to those comments. The Introduction to Volume III describes how DOE solicited comments on the Draft EIS and the Supplement to the Draft EIS, the methodology it used to extract, categorize, and respond to public comments, a summary of the key issues raised in the comments, a discussion on how to use the Comment-Response Document, and index tables that list organizations and individuals who submitted comments. The Introduction also lists the chapters in Volume III, which relate to the following topics:

- Proposed Action
- Nuclear Waste Policy Act
- National Environmental Policy Act
- Other Legal, Regulatory, and Policy Issues
- Alternatives
- Spent Nuclear Fuel and High-Level Radioactive Waste
- Repository Design, Performance, and Affected Environment
- Transportation Modes, Routes, Affected Environment, and Impacts
- No-Action Alternative
- Cumulative Impacts

- Impact Mitigation and Compensation

- DOE Credibility

- Comments Outside the Scope of the Environmental Impact Statement and the Yucca Mountain Site Characterization Project

The chapters in Volume III contain every comment received on a timely basis (see the Introduction to the Comment-Response Document) on each topic, and, in some cases, subtopic. Because a number of comments were similar in nature, DOE summarized them. The chapters also contain the DOE responses to all the comments, either individual or summarized.

Final

Environmental Impact Statement
for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Summary

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COVER SHEET

RESPONSIBLE AGENCY: U.S. Department of Energy (DOE)

TITLE: *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250)

CONTACT: For more information on this Final Environmental Impact Statement (EIS), write or call:

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Information on this EIS is available on the Internet at the Yucca Mountain Project web site at *http://www.ymp.gov* and on the DOE National Environmental Policy Act (NEPA) web site at *http://tis.eh.doe.gov/nepa/*.

For general information on the DOE NEPA process, write or call:

Carol M. Borgstrom, Director
Office of NEPA Policy and Compliance (EH-42)
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
Telephone: (202) 586-4600, or leave a message at (800) 472-2756

ABSTRACT: The Proposed Action addressed in this Final EIS is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain in southern Nevada for the disposal of spent nuclear fuel and high-level radioactive waste currently in storage or projected to be generated at 72 commercial and 5 DOE sites across the United States. The EIS evaluates (1) projected impacts on the Yucca Mountain environment of the construction, operation and monitoring, and eventual closure of the geologic repository; (2) the potential long-term impacts of repository disposal of spent nuclear fuel and high-level radioactive waste; (3) the potential impacts of transporting these materials nationally and in the State of Nevada; and (4) the potential impacts of not proceeding with the Proposed Action. The preferred alternative is to proceed with the Proposed Action and to use mostly rail, both nationally and in Nevada, to transport spent nuclear fuel and high-level radioactive waste.

PUBLIC COMMENTS: In preparing this EIS, DOE considered comments received by letter, electronic mail, facsimile transmission, and oral and written comments given at public hearings at 21 locations across the United States on the Draft EIS, and at 3 locations in Nevada for the Supplement to the Draft EIS.

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OVERVIEW

The purpose of this environmental impact statement (EIS) is to provide information on potential environmental impacts that could result from a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at the Yucca Mountain site in Nye County, Nevada. The EIS also provides information on potential environmental impacts from an alternative referred to as the No-Action Alternative, under which there would be no development of a geologic repository at Yucca Mountain.

U.S. Department of Energy Actions

The Nuclear Waste Policy Act, enacted by Congress in 1982 and subsequently amended, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the Nuclear Waste Policy Act, as amended in 1987 (the EIS refers to the amended Act as the NWPA), requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, accompany the recommendation. The Department of Energy (DOE) has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS, in making a decision on whether to recommend the site to the President.

The NWPA requires DOE to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, and after considering other information, the Secretary decided to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after any such notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

Presidential Recommendation and Congressional Action

If, after a recommendation by the Secretary, the President considered the site qualified for application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may object to the recommendation of the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submits such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature submits such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

Actions To Be Taken after Site Designation

If a site designation became effective, the NWPA provides that the Secretary of Energy shall submit to the Nuclear Regulatory Commission an application for a construction authorization for a repository no later than 90 days after the date on which the recommendation of the site designation becomes effective. The NWPA requires the Nuclear Regulatory Commission to adopt DOE's Final EIS to the extent practicable as part of the Nuclear Regulatory Commission's decisionmaking on the License Application.

Decisions Related to Potential Environmental Impacts Considered in the EIS

This EIS analyzes a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a No-Action Alternative, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a basis for comparison with the Proposed Action.

As part of the Proposed Action, which DOE has identified as its preferred alternative, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation nationally and in Nevada, as well as impacts in Nevada of alternative intermodal (rail-to-truck) transfer stations, associated routes for heavy-haul trucks, and alternative corridors for a branch rail line.

DOE believes that the EIS provides the environmental impact information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada. At this time, however, the Department has not identified a preference among the five potential rail corridors in Nevada.

If the Yucca Mountain site was approved (designated), DOE would issue at some future date a Record of Decision to select a mode of transportation. If, for example, mostly rail was selected (both nationally and in Nevada), DOE would then identify a preference for one of the rail corridors in consultation with affected stakeholders, particularly the State of Nevada. In this example, DOE would announce a preferred corridor in the *Federal Register* and other media. No sooner than 30 days after the announcement of a preference, DOE would publish its selection of a rail corridor in a Record of Decision. A similar process would occur in the event that DOE selected heavy-haul truck as its mode of transportation in the State of Nevada. Other transportation decisions, such as the selection of a specific rail alignment within a corridor, would require additional field surveys, State and local government and Native American tribal consultations, environmental and engineering analyses, and appropriate National Environmental Policy Act reviews.

S.1 The National Environmental Policy Act

DOE prepared the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* to provide the background, data, and analyses to help decisionmakers and the public understand the potential environmental impacts of the proposed repository. The Department issued the Draft EIS, dated July 1999, for public comment; a 199-day comment period began August 13, 1999, and ended on February 28, 2000. In May 2001, DOE issued the *Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada,* which was the subject of a public comment period that ended on July 6, 2001. The comment period was extended to August 13, 2001, for about 700 reviewers inadvertently omitted from the mailing list. In Volume III of this EIS, DOE has presented and responded to all comments on the Draft EIS and the Supplement to the Draft EIS received by August 31, 2001. All comments received by DOE after August 31, 2001, were responded to as time and resources permitted. However, all comments received after August 31, 2001, whether or not responded to, were considered by the Department. Based on this consideration, the Department concluded that none raised new issues not already reflected in timely comments and already considered. DOE has prepared this *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* consistent with the National Environmental Policy Act (NEPA) and the Nuclear Waste Policy Act, as amended. This Final EIS updates information in the Draft EIS and Supplement, provides additional information, and responds to public comments.

S.2 Purpose and Need for Agency Action

S.2.1 PURPOSE AND NEED

For many years civilian and defense-related activities have produced spent nuclear fuel and high-level radioactive waste. These materials have accumulated—and continue to accumulate—at 72 commercial and 5 DOE sites across the United States. Figure S-1 shows the locations of these sites and Yucca Mountain.

In passing the Nuclear Waste Policy Act in 1982, Congress affirmed that the Federal Government is responsible for the permanent disposal of spent nuclear fuel and high-level radioactive waste. In the 1987 amendments to the Act, Congress directed the Secretary of Energy to determine whether to recommend that the President approve the Yucca Mountain site for development of a repository for the permanent disposal of these materials.

S.2.2 BACKGROUND

DOE is responsible for implementing a permanent solution for the management of spent nuclear fuel and high-level radioactive waste. *Spent nuclear fuel* is fuel that has been withdrawn from a nuclear reactor following irradiation; it consists mostly of uranium, and is usually intensely radioactive because it also contains a high level of radioactive nuclear fission products. Commercial spent nuclear fuel was used in civilian nuclear reactors to produce electricity. The majority of DOE spent nuclear fuel comes from defense production reactors, naval propulsion plant reactors, and test and experimental reactors. In addition to conventional uranium fuel, DOE is responsible for the disposition of weapons-usable plutonium that is surplus to national security needs. This EIS includes analysis of surplus weapons-usable plutonium that DOE plans to convert to mixed-oxide (uranium and plutonium) fuel as part of the commercial spent nuclear fuel inventory and surplus weapons-grade plutonium that DOE plans to immobilize and include as part of the high-level radioactive waste inventory.

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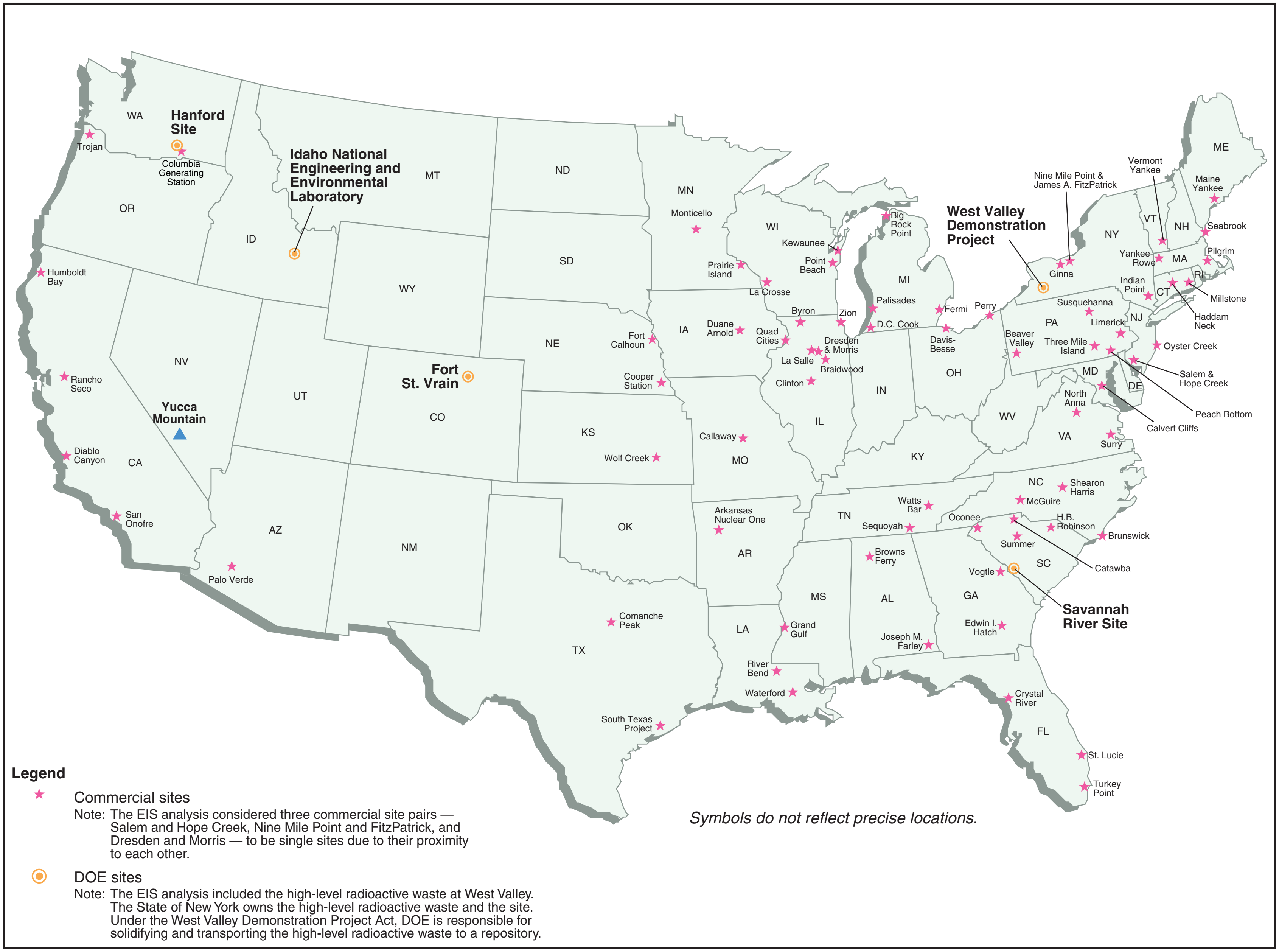


Figure S-1. Locations of commercial and DOE sites and Yucca Mountain.

When the DOE production reactors were operating, they used a controlled fission process to irradiate nuclear fuel and produce materials for nuclear weapons. After the spent nuclear fuel was removed from the reactors, chemical processes extracted the weapons-usable materials from the spent nuclear fuel. This is called *reprocessing*.

The byproduct remaining after reprocessing is *high-level radioactive waste*. High-level radioactive waste also resulted from the reprocessing of naval reactor fuels and some commercial reactor fuels, some DOE test reactor fuels, and some non-DOE research reactor fuels.

The Proposed Action includes disposal of spent nuclear fuel and high-level radioactive waste. In addition, DOE is responsible for the disposal of other waste types, referred to as *Greater-Than-Class-C* and *Special-Performance-Assessment-Required* wastes. These waste types are low-level radioactive wastes that have high radionuclide concentrations. They could become eligible for disposal in a geologic repository in the future, so DOE has analyzed the cumulative environmental impacts associated with the potential disposal of these wastes in a repository at Yucca Mountain.

MATERIALS EVALUATED IN THIS EIS

Spent nuclear fuel is fuel that has been withdrawn from a reactor following irradiation.

- **Commercial** – from civilian nuclear powerplants that generate electricity (including mixed-oxide fuel)
- **DOE** – from DOE production reactors, naval reactors, test and experimental reactors, and research reactors (including some non-DOE reactors)

High-level radioactive waste is primarily waste that resulted from the chemical extraction of weapons-usable materials from the spent nuclear fuel. Immobilized surplus weapons-usable plutonium is part of the high-level radioactive waste inventory.

Greater-Than-Class-C waste is low-level radioactive waste generated by commercial nuclear reactors that does not meet shallow land burial disposal limits.

Special-Performance-Assessment-Required waste is low-level radioactive wastes generated in DOE production reactors, research reactors, reprocessing facilities, and research and development activities that exceed the Nuclear Regulatory Commission Class C shallow-land burial disposal limits.

S.2.2.1 Legislative History

Methods to dispose of radioactive wastes have been studied since the late 1950s. In 1980, President Carter declared that the safe disposal of radioactive waste generated by both defense and civilian nuclear activities is a national responsibility. In the *Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DOE/EIS-0046, 1980), DOE analyzed the environmental impacts that could occur if it implemented alternative strategies for the management and disposal of spent nuclear fuel. The disposal alternatives included mined geologic disposal, very deep hole waste disposal, disposal in a mined cavity that results in rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal (for example, launching waste into orbit around the sun), and no action. The Record of Decision for that EIS, issued in 1981, announced the DOE decision to pursue the mined geologic disposal alternative.

In 1982, Congress enacted the Nuclear Waste Policy Act in recognition of the need to provide for the permanent disposal of spent nuclear fuel and high-level radioactive waste in the United States. This Act established the Federal Government's responsibility to provide permanent disposal of the Nation's spent nuclear fuel and high-level radioactive waste and set forth a process and schedule for the disposal of these materials in a geologic repository. In 1986, following the process outlined in the original Nuclear Waste Policy Act, DOE narrowed the number of potentially acceptable sites for a geologic repository to three: Deaf Smith County in Texas; the Hanford Site in Washington; and Yucca Mountain. President Reagan approved the DOE recommendation of these sites as suitable for site characterization. In 1987, Congress amended the Nuclear Waste Policy Act and directed the Secretary of Energy to characterize only Yucca Mountain as a potential location for a geologic repository, setting forth a process for the Federal Government to decide whether to designate Yucca Mountain as the site for a repository.

The site characterization program consists of scientific, engineering, and technical studies and activities. Site investigations and evaluations include the construction of the Exploratory Studies Facility, which is a large underground laboratory consisting of a long tunnel or *main drift* and side tunnels and rooms inside the mountain; investigations of the hydrology and geology of the site; studies of socioeconomics, cultural resources, and terrestrial ecosystems; and monitoring of air quality, meteorological, radiological, and water resource data.

SITE CHARACTERIZATION OF YUCCA MOUNTAIN

DOE has had a program of investigations and evaluations to assess the characteristics of Yucca Mountain as a potential monitored geologic repository and to provide information for this environmental impact statement. Data from site characterization activities have been used to describe the existing environment at the Yucca Mountain site and to assess the potential impacts of the proposed repository.

S.2.2.2 Related Activities and Decisions

Decision Process for Site Recommendation. Under the NWPA, DOE is required to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the site to the President. If, after completion of the hearings and site characterization activities, the Secretary decides to recommend that the President approve Yucca Mountain, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository. The NWPA further requires that the Secretary's recommendation to the President be based on the record of information developed through the site characterization program, as well as other sources, including the Final EIS. The Secretary will consider the Final EIS, as well as comments from Federal, state, local, and tribal governments, other organizations, and interested individuals on the Draft EIS and the Supplement to the Draft EIS in making a determination on whether to recommend the site to the President.

If the Secretary recommends the Yucca Mountain site to the President, the NWPA requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, accompany the recommendation. Since issuing the Draft EIS and the Supplement to the Draft EIS, DOE has issued several publicly available documents that would form part of this comprehensive statement. These documents address such topics as:

- Baseline postclosure models for Total System Performance Assessment
- Preliminary engineering specifications, including definitions of repository operating modes
- Preclosure safety analysis
- Sensitivity studies using alternative models and data

- Analyses of unquantified uncertainties
- Updates of scientific information and analysis of long-term performance of the lower-temperature repository operating mode
- Preliminary evaluation of the suitability of the Yucca Mountain site for a repository

The key documents that were issued for public review and comment in support of a potential site recommendation include:

- *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration,* May 2001
- *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation,* July 2001
- *FY01 Supplemental Science and Performance Analysis,* July 2001
- *Yucca Mountain Preliminary Site Suitability Evaluation,* August 2001
- *Total System Performance Assessment-Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain-Inputs to Final Environmental Impact Statement and Site Suitability Evaluation, August 2001.*

DOE has established guidelines (10 CFR Part 963) for evaluating the suitability of the Yucca Mountain site by assessing how specific design concepts would work within the natural system and by comparing the results of these assessments to the applicable regulatory standards. As required by the NWPA, DOE would apply these guidelines in determining the suitability of Yucca Mountain as a site for a repository.

REGULATORY STANDARDS

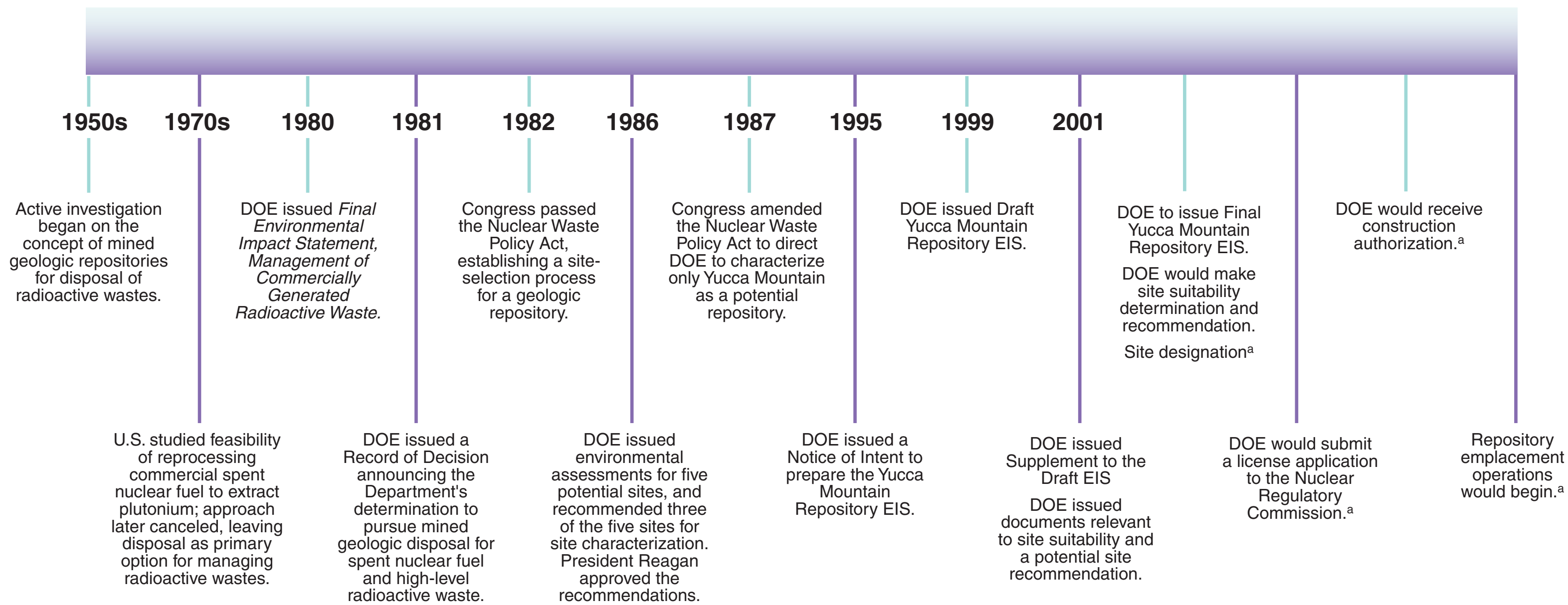
40 CFR Part 197: *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, NV* issued by the Environmental Protection Agency.

10 CFR Part 63: *Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV* issued by the Nuclear Regulatory Commission.

10 CFR Part 963: *General Guidelines for Nuclear Waste Repositories*; Yucca Mountain Site Suitability Guidelines issued by DOE.

Decision Process for U.S. Nuclear Regulatory Commission Licensing. If the Yucca Mountain site is approved, DOE will submit a License Application to the Nuclear Regulatory Commission for authorization to construct a geologic repository. The NWPA directs the Commission to adopt the Final EIS to the extent practicable in its decision on whether to issue a construction authorization and license for such a repository.

The Nuclear Regulatory Commission has issued requirements governing its licensing of DOE to construct a geologic repository and to receive and possess nuclear material at that repository (10 CFR Part 63). As mandated by law, these requirements are required to be consistent with the final standards for Yucca Mountain issued by the Environmental Protection Agency (40 CFR Part 197). Figure S-2 shows the sequence of past disposal decisions and projected activities.



a. If Yucca Mountain was approved.

Figure S-2. Sequence of past disposal decisions and future repository activities.

S.3 Proposed Action and No-Action Alternative

S.3.1 PROPOSED ACTION

Under the Proposed Action, DOE would construct, operate and monitor, and eventually close a geologic repository for the disposal of 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The Proposed Action would include the transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the Yucca Mountain site.

DEFINITION OF METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

DOE would dispose of spent nuclear fuel and high-level radioactive waste in the repository using the natural geologic features of the mountain and engineered barriers as a total system to help ensure the long-term isolation of the materials from the accessible environment. DOE would build the repository inside Yucca Mountain, at least 200 meters (660 feet) below the surface and at least 160 meters (530 feet) above the present-day water table. Figure S-3 shows the location of the proposed repository at Yucca Mountain.

In addition, the Proposed Action would include the use of active institutional controls (controlled access, inspection, and maintenance, etc.) through the end of the closure period, and the use of passive institutional controls (markers, engineered barriers, etc.) after the completion of closure. The purpose of the passive institutional controls would be to prevent inadvertent intrusion by and exposures to members of the public.

S.3.1.1 Repository and Waste Package Design

The repository would be a large underground excavation with a number of interconnecting tunnels (called drifts) that DOE would use for waste emplacement. Figure S-4 shows the proposed repository concept.

The Draft EIS evaluated the preliminary design concept described in the 1998 *Viability Assessment of a Repository at Yucca Mountain.* DOE recognized when it published the Draft EIS that plans for a repository would continue to evolve during any development of a final repository design and as a result of any licensing review of the repository by the Nuclear Regulatory Commission. Later, DOE

PREFERRED ALTERNATIVE

DOE's preferred alternative is to proceed with the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain.

DOE has also identified a preferred mode (the mostly rail scenario) of transporting spent nuclear fuel and high-level radioactive waste to the proposed repository. The smaller number of shipments required to transport 70,000 MTHM of spent nuclear fuel and high-level radioactive waste by the mostly rail scenario, coupled with the correspondingly reduced environmental impacts, form the basis for DOE's preference of the mostly rail scenario, both nationally and in Nevada.

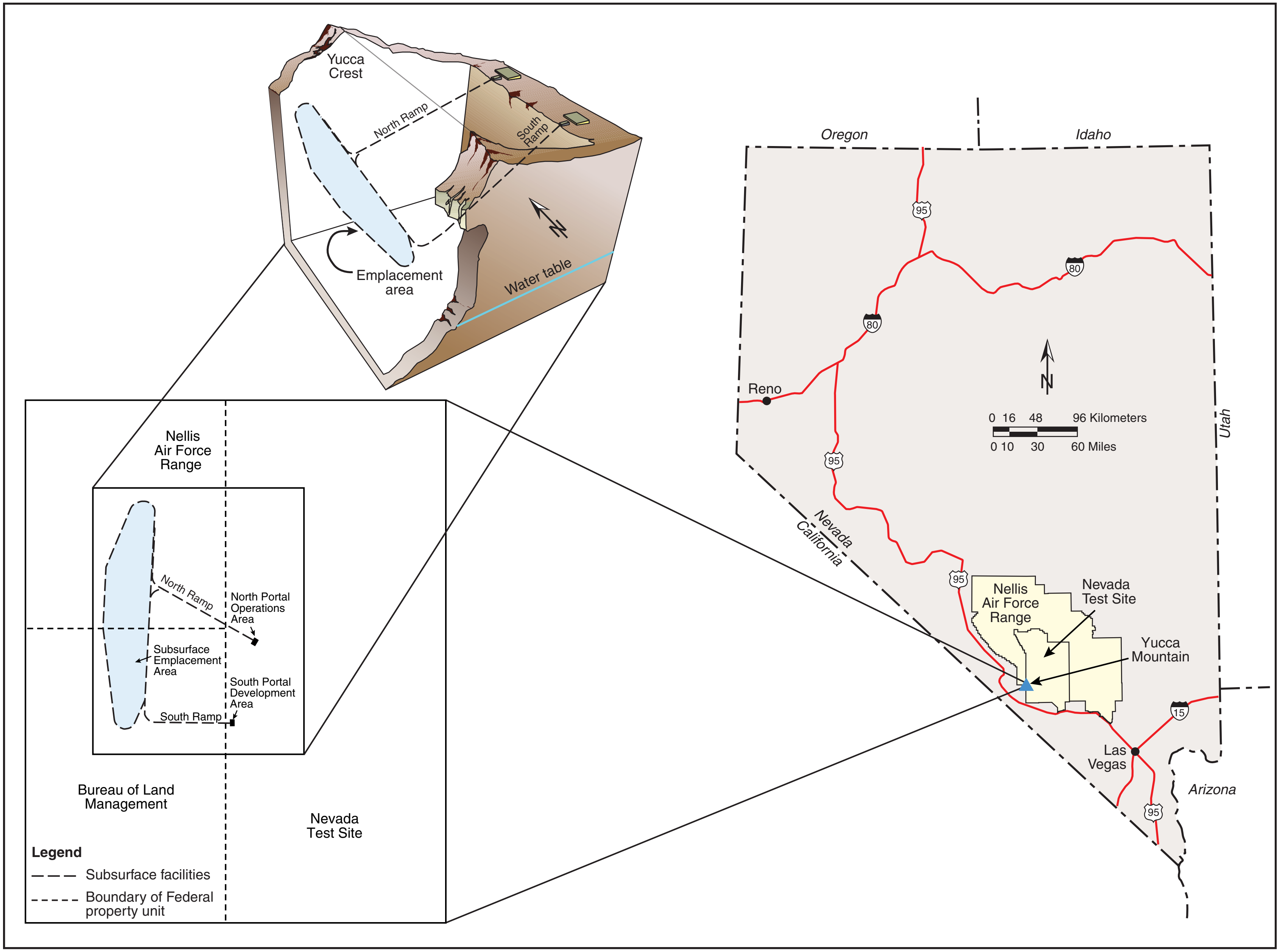


Figure S-3. Location of the proposed repository at Yucca Mountain.

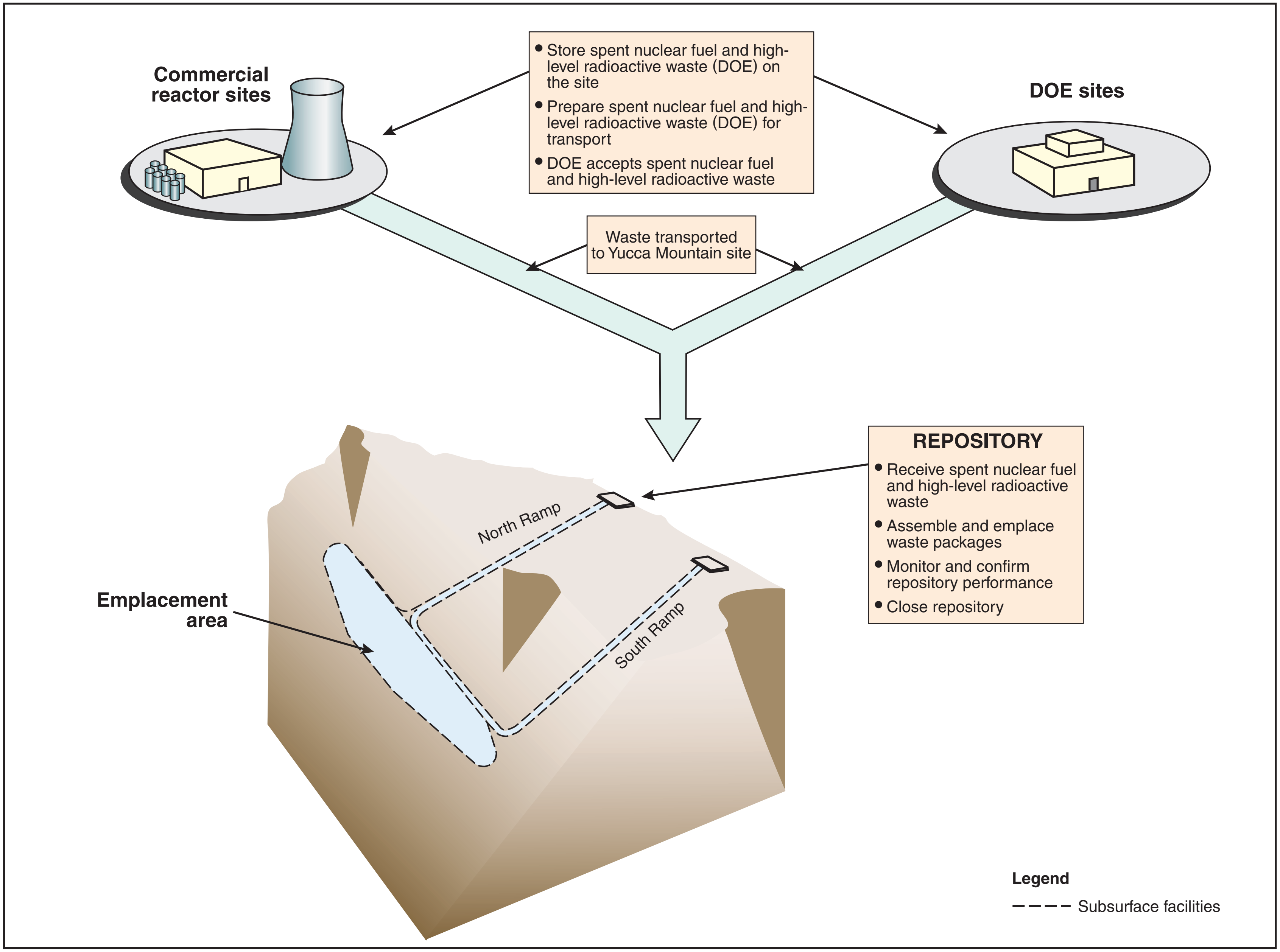


Figure S-4. Spent nuclear fuel and high-level radioactive waste handling, transportation, and disposal.

issued the Supplement to the Draft EIS that evaluated the repository design described in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration,* which it issued in May 2001. The flexible design analyzed in the Supplement includes an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. Rather than analyzing the three thermal load scenarios (high, intermediate, and low thermal loads) as in the Draft EIS, the Final EIS analyzes a range of operating modes (higher- to lower-temperature) for the flexible design. Because (1) thermal load is no longer the descriptive parameter for specifying thermal management scenarios for the proposed repository, and (2) an effort was made in the Final EIS to avoid confusion and to clarify the impacts of the Proposed Action, DOE has not carried the earlier thermal load scenarios through to the Final EIS. (A comparison between the thermal load scenarios and the repository operating modes for the flexible design is provided in the Supplement to the Draft EIS.)

FLEXIBLE DESIGN

The flexible design includes the ability to operate the proposed repository in a range of operating modes that are characterized by higher and lower temperatures and associated humidity conditions. *Higher-temperature* means that at least a portion of the emplacement drift rock wall would have a maximum temperature above the boiling point of water at the elevation of the repository. The ranges analyzed for the *lower-temperature* operating mode include conditions under which the drift rock wall temperatures would be below the boiling point of water, and under which the surface temperature of the waste package would not exceed 85°C (185°F).

Modifications from the repository design introduced in the Draft EIS and analyzed in the Supplement to the Draft EIS include:

- The ability to blend hotter and cooler commercial spent nuclear fuel assemblies (the assemblies produce most of the heat generated by waste materials in a geologic repository) to control the heat generation of waste packages
- The flexibility to include a facility on the surface for aging (that is, cooling) of hotter commercial spent nuclear fuel to control the heat of waste packages
- Increased ventilation (forced and natural) to enable a cooler repository
- Increased spacing between emplacement drifts to allow a moisture pathway between drifts
- The operational flexibility to vary the spacing between the waste packages in a drift to manage the heat load
- Modified waste packages and the addition of titanium drip shields to improve overall performance and divert moisture

The purpose of the flexible design is to improve the long-term performance of the proposed repository, and reduce associated uncertainties.

DOE would receive materials at the repository in one of three configurations: uncanistered fuel (spent nuclear fuel placed directly in a shipping cask), dual-purpose canisters (containers designed to store and transport commercial spent nuclear fuel), or disposable canisters (canisters for spent nuclear fuel or high-level radioactive waste with multiple specialized overpacks to enable their storage, transportation, and emplacement in a repository). All DOE materials (spent nuclear fuel and high-level radioactive waste) would be received in disposable canisters. Commercial spent nuclear fuel would be received in any of the three packaging configurations. DOE cannot predict the particular combination of uncanistered fuel, dual-purpose canisters, or disposable canisters it would receive at a repository because the managers of the commercial sites would determine the canister type, if any, they will use. For that reason, in the Draft EIS the Department analyzed two fuel packaging scenarios [mostly uncanistered and mostly canistered (including dual-purpose canisters and disposable canisters)] that cover the possible range of repository and transportation impacts to human health and the environment. DOE's analysis shows that the mostly uncanistered fuel packaging scenario would result in the highest short-term impacts, with the exception of (1) the empty dual-purpose canisters that some commercial sites could use that would require disposal or recycling, and (2) some attributes of offsite manufacturing of disposable canisters. To simplify the presentation in this Final EIS, the impacts throughout this document include those associated with the mostly uncanistered fuel packaging scenario, plus the impacts of the waste management and offsite manufacturing impacts, which are also included to represent potential impacts associated with the canistered scenario. This approach ensures that the impacts presented in this Final EIS would bound the impacts of any packaging scenario ultimately selected.

DEFINITIONS OF PACKAGING TERMS

Shipping cask: A vessel that meets applicable regulatory requirements for shipping spent nuclear fuel or high-level radioactive waste.

Dual-purpose canister: A metal vessel suitable for storing (in a storage facility) and shipping (in a shipping cask) commercial spent nuclear fuel assemblies. At the repository, dual-purpose canisters would be removed from the shipping cask and opened. The spent nuclear fuel assemblies would be removed from the canister and placed in a disposal container or in the fuel pool to accommodate blending. The opened canister would be recycled or disposed of offsite as low-level radioactive waste.

Disposable canister: A metal vessel for commercial or DOE spent nuclear fuel assemblies or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, the disposable canister would be removed from the shipping cask and placed directly in a disposal container. The disposable canister is sometimes referred to as a multi-purpose canister in discussions of repository design.

Uncanistered spent nuclear fuel: Commercial spent nuclear fuel placed directly into shipping casks. At the repository, spent nuclear fuel assemblies would be removed from the shipping cask and placed in a disposal container or in the fuel pool to accommodate blending.

Disposal container: A container for spent nuclear fuel and high-level radioactive waste consisting of the barrier materials and internal components. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

Waste package: The filled, sealed, and tested disposal container that would be emplaced in the repository.

Material received at the repository would be unloaded from the shipping casks and placed in disposal containers called *waste packages*. To control the heat generation of the waste packages, the flexible design includes thermal blending of commercial spent nuclear fuel assemblies. Remote-controlled transporters would place the waste packages in emplacement drifts.

DOE considered waste packages containing two layers—a corrosion-resistant Alloy-22 shell on the outside and a stainless-steel inner shell to provide structural support. The highly corrosion-resistant outer

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material of the waste package would protect the underlying structural material from corrosive degradation, while the extremely strong internal structural material would support the thinner corrosion-resistant material. A drip shield of titanium (also extremely corrosion-resistant) with a nominal thickness of 1.5 centimeters (0.6 inch) would be placed over the waste packages during the closure phase. With the titanium drip shield and the Alloy-22 outer cylinder, there would be two different corrosion barriers protecting the waste from contact with water. Further, the use of two distinctly different corrosion-resistant materials would reduce the probability that a single mechanism could cause failure in both materials. The waste packages, together with the titanium drip shields, would be the primary part of an engineered barrier system in the repository. This system would, in combination with the natural features of this site, help slow the release of radioactive material to the accessible environment for long periods.

NATURAL AND ENGINEERED FEATURES

Water is the primary means by which radionuclides disposed of at Yucca Mountain could reach the accessible environment. The natural features of the very dry climate, large distance to the water table, and geology of the site would act to limit the amount of water that entered the repository. The engineered features, including drip shields and waste packages made from corrosion-resistant material, would deter releases of radioactive material, even in the presence of any water that reached the emplacement area.

Under the Proposed Action, DOE would emplace approximately 11,000 to 17,000 waste packages containing no more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the repository. Of that amount, 63,000 MTHM would be spent nuclear fuel assemblies that would be shipped from commercial sites to the repository. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel and the equivalent of 4,667 MTHM of high-level radioactive waste, currently estimated to be approximately 8,315 canisters, that DOE would ship to the repository from DOE sites. The inventory includes surplus weapons-usable plutonium. At present, DOE expects two-thirds of the plutonium would be converted into mixed-oxide fuel, which is included as part of the commercial spent nuclear fuel inventory. DOE expects the remaining third of the plutonium to be immobilized and included in the high-level radioactive waste inventory.

Figure S-5 shows potential waste package designs for commercial spent nuclear fuel. Figure S-6 shows waste packages in an emplacement drift.

S.3.1.2 Preconstruction Testing and Performance Confirmation, Construction, Operation and Monitoring, and Closure

DOE would construct and operate surface facilities at the repository site to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for emplacement in underground drifts. The surface and subsurface facilities developed for site characterization activities at Yucca Mountain would be incorporated into the repository design to the extent practicable. Figures S-7 and S-8 show conceptual designs of the surface and subsurface facilities, respectively. Figure S-9 shows the sequence for repository development at Yucca Mountain.

Preconstruction Testing and Performance Confirmation. The preconstruction Testing and Performance Confirmation Program would continue many of the same types of activities performed during site characterization and would include tests, experiments, and analyses that DOE would conduct to evaluate the long-term performance of the repository. Before the start of repository construction, this program would assume responsibility for activities now being performed as part of site characterization. Those activities would continue until closure of the repository.

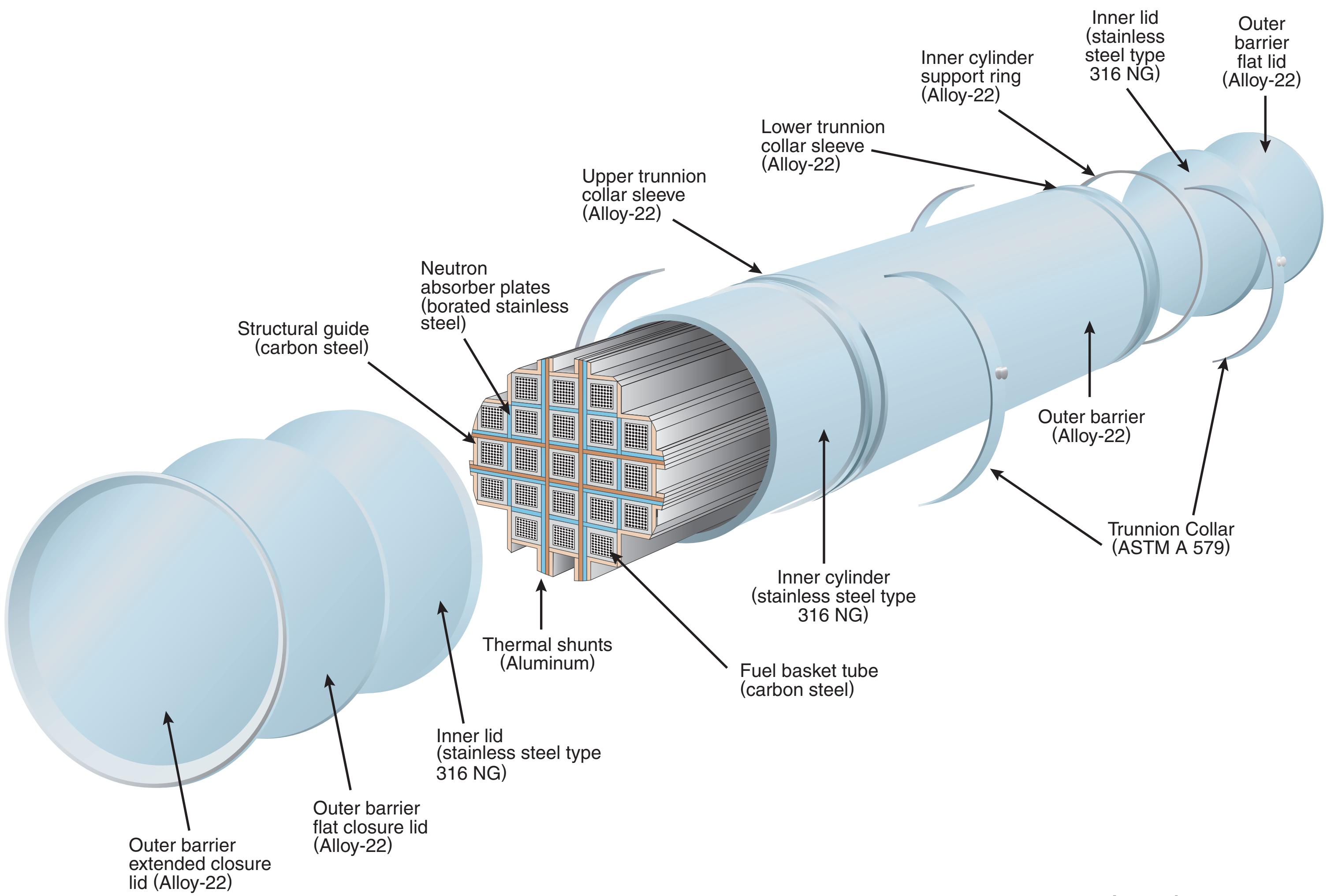

Figure S-5. Waste package for commercial spent nuclear fuel (pressurized-water reactor waste package).

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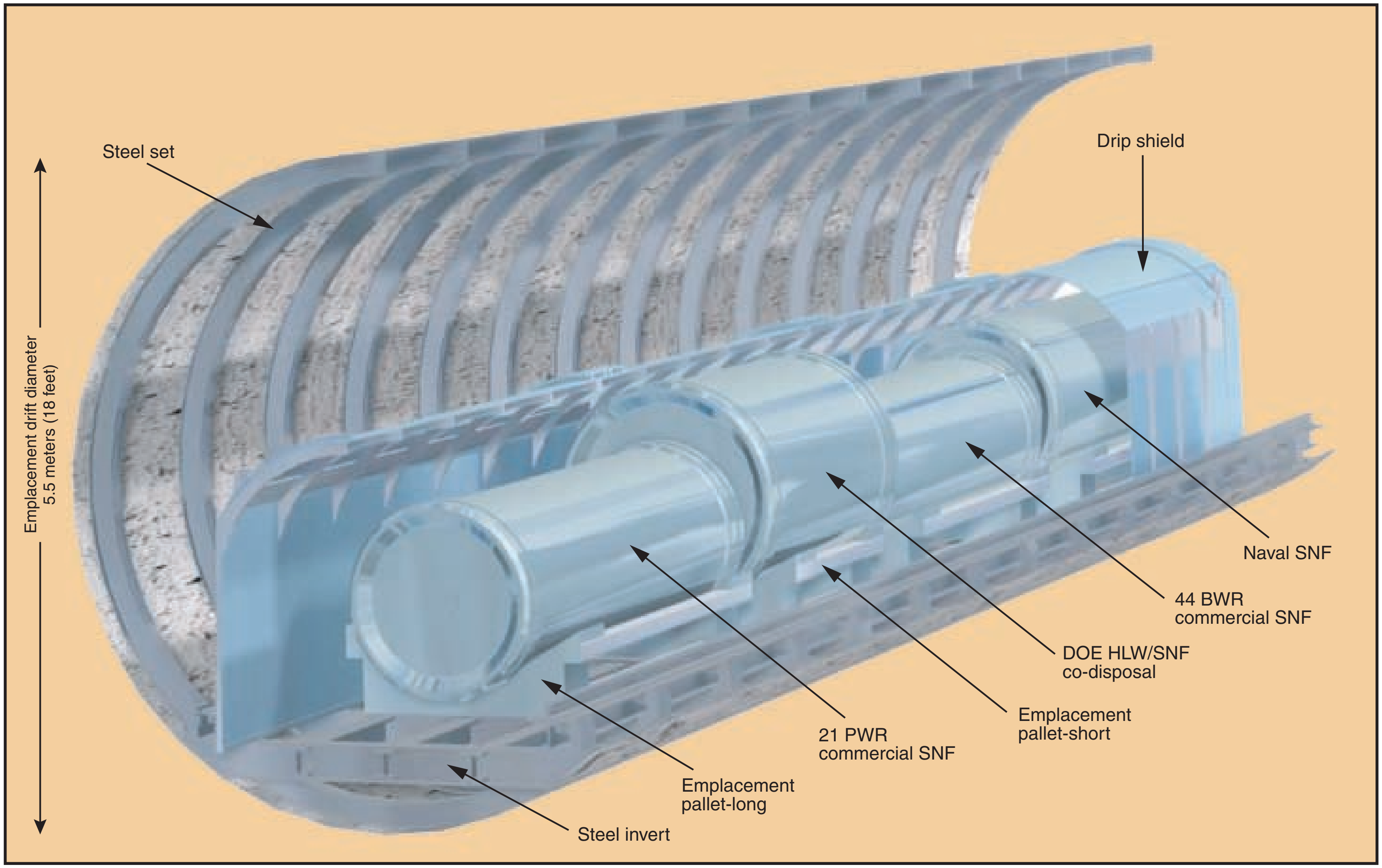

Drawing not to scale.

Legend

BWR Boiling-water reactor
DOE U.S. Department of Energy
HLW High-level radioactive waste
PWR Pressurized-water reactor
SNF Spent nuclear fuel

Figure S-6. Typical section of emplacement drift with waste packages and drip shields in place.

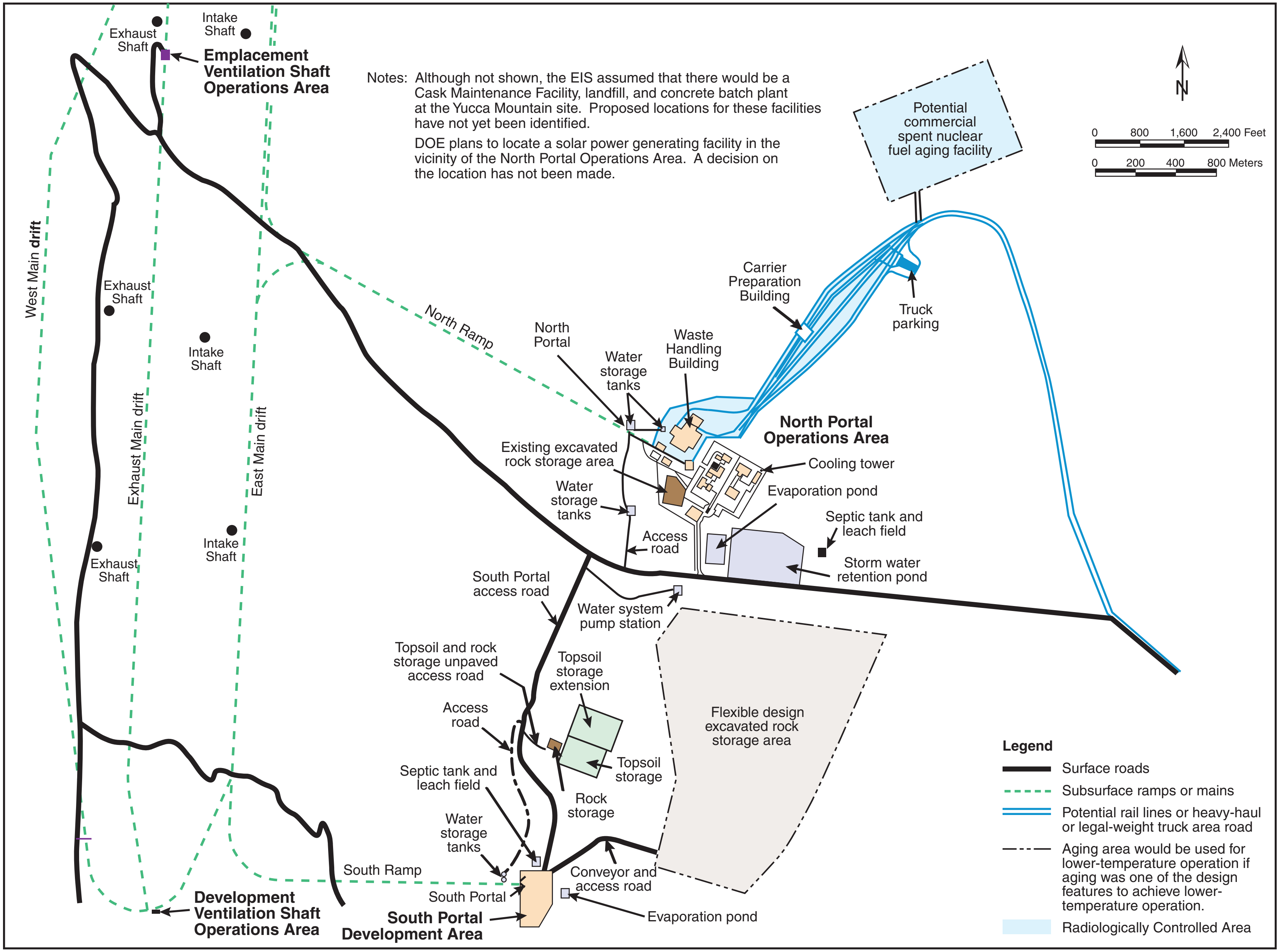

Figure S-7. Potential repository surface facilities site plan.

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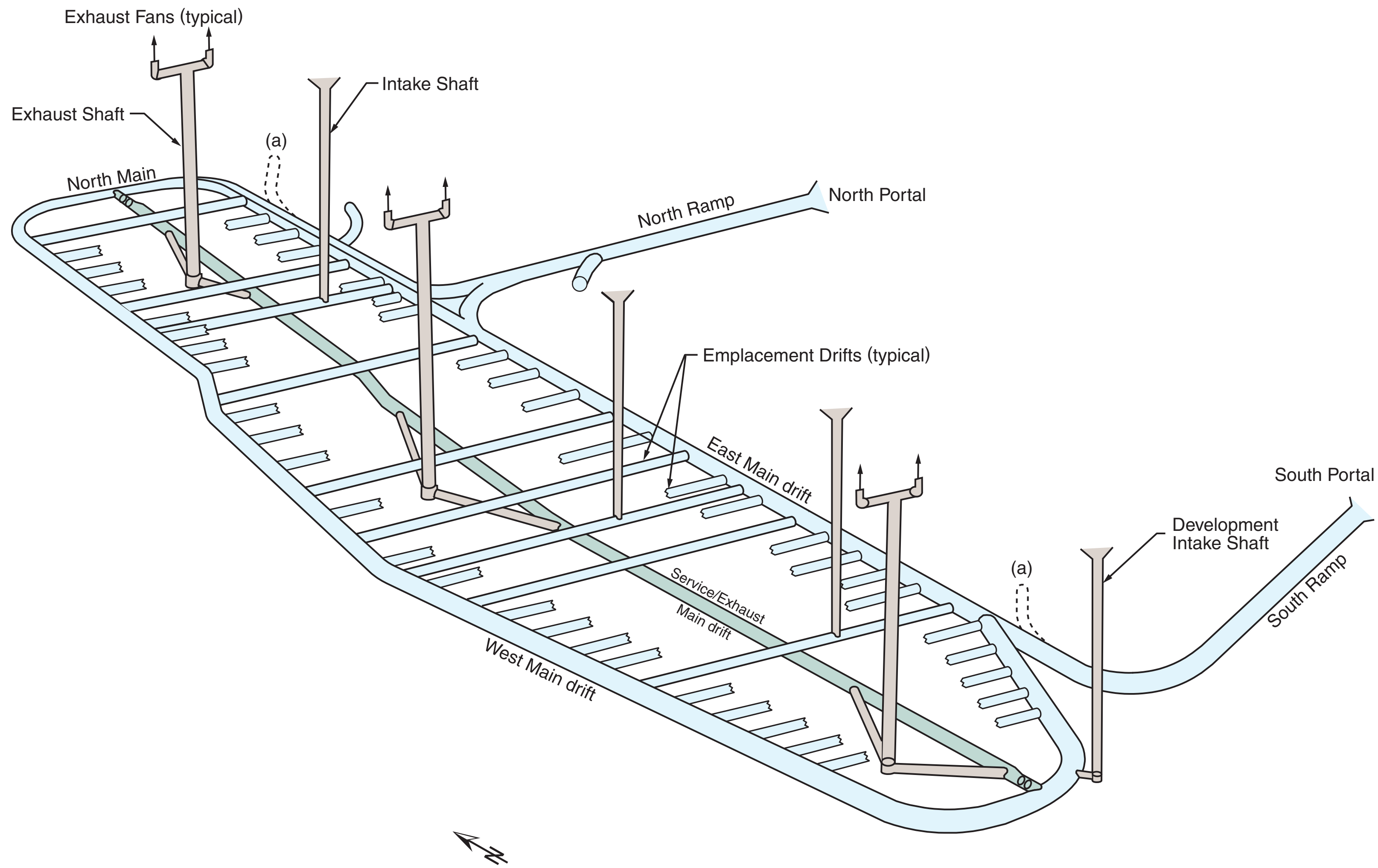

Note: (a) Potential connection to lower block

Drawing not to scale.

Figure S-8. Repository subsurface facility plan (higher-temperature repository operating mode).

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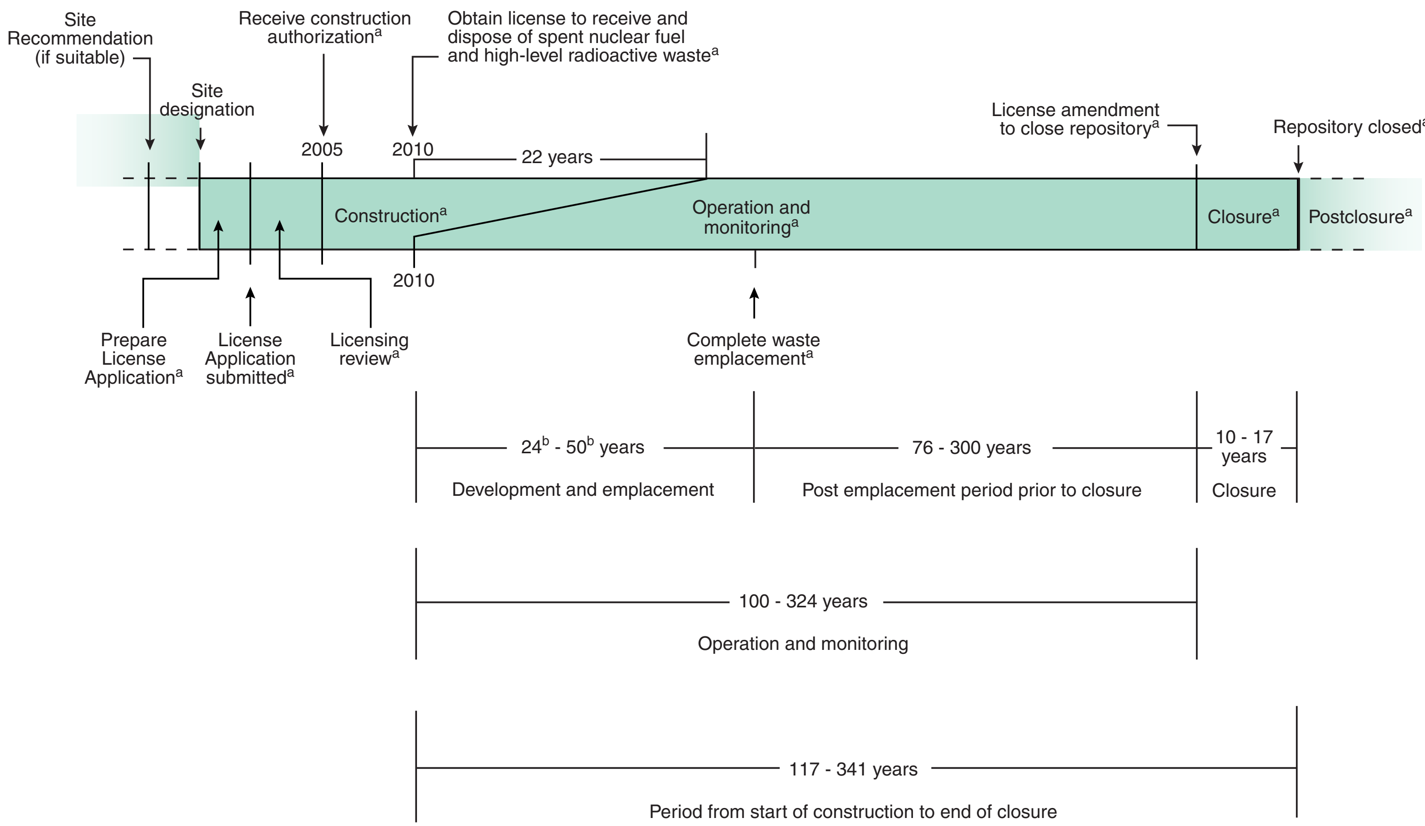

a. If Yucca Mountain is approved.

b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Figure S-9. Monitored geologic repository range of milestones used for analysis.

Construction. The construction of repository surface and subsurface facilities could begin after the receipt of construction authorization from the Nuclear Regulatory Commission. For analytical purposes, DOE assumed that construction would begin in 2005. The Department would build the repository surface facilities, main drifts, ventilation system, and initial emplacement drifts in about 5 years, from 2005 to 2010. Construction of the emplacement drifts would continue after emplacement began.

Surface facilities would receive, prepare, and package spent nuclear fuel and high-level radioactive waste for emplacement, and would support the construction of subsurface facilities. The primary surface facilities would be the *North Portal Operations Area* (including the *Waste Handling Building* and a *surface aging facility* if DOE employed aging of commercial spent nuclear fuel in conjunction with the lower-temperature repository operating mode), the *South Portal Development Area* (supporting subsurface facility development), and a 3-megawatt *solar power generating facility* that DOE would use to meet some of the electrical energy requirements of the repository.

Subsurface facilities would include the drifts developed during site characterization activities. During construction, additional underground excavation would occur. Excavation in the subsurface facilities would include gently sloping *access ramps* for the movement of construction and waste package vehicles, *main drifts* for the movement of construction and waste package vehicles, *emplacement drifts* for the placement of waste packages, *exhaust mains* to transfer air in the subsurface area, and *ventilation shafts* to transfer air between the surface and the subsurface. The higher-temperature repository operating mode would require three emplacement intake shafts, one development intake shaft, and three exhaust shafts to support the full emplacement of 70,000 MTHM. The lower-temperature repository operating mode could require three to seven emplacement intake shafts, one development intake shaft, and five to nine exhaust shafts. *Performance confirmation drifts* would contain instrumentation to monitor emplaced waste packages.

Operation and Monitoring. Repository operations would begin after the Nuclear Regulatory Commission granted a license to "receive and possess" spent nuclear fuel and high-level radioactive waste. For planning purposes, DOE assumed that the receipt and emplacement of these materials would begin in 2010. Based on a total emplacement of 70,000 MTHM at approximately 3,000 MTHM each year, waste emplacement would end after approximately 24 years.

Under the lower-temperature repository operating mode, DOE could place commercial spent nuclear fuel on a surface aging pad in Nuclear Regulatory Commission-licensed storage casks. This aging was assumed to occur during a 50-year period and would allow the heat generated by radioactive decay to be reduced before emplacing the waste packages into the repository.

The construction of emplacement drifts would continue for approximately 22 years during operation and monitoring. The repository design would enable simultaneous construction and emplacement operations, but it would physically separate construction or development activities from emplacement activities. Ventilation barriers would create airlocks to separate the emplacement and development sides of the repository, and the ventilation system would be designed to maintain the emplacement side at a lower pressure than the development side. This would ensure that no air leakage would occur from the emplacement side to the development side.

Monitoring and maintenance activities would begin with the first emplacement of waste packages and would continue until repository closure. The monitoring period, as defined for analytical purposes, would begin after the completion of emplacement. During the monitoring period, DOE would maintain the repository facilities, including the ventilation system and utilities (air, water, electric power) that would enable the continued monitoring and inspection of waste packages, continued investigations of long-term repository performance, and the retrieval of waste packages, if necessary. Immediately after

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RETRIEVAL

Section 122 of the NWPA requires DOE to maintain the ability to retrieve emplaced materials. Because of this requirement, the EIS includes an analysis of the impacts of retrieval. Although the EIS analyzes it, DOE does not believe that retrieval would be necessary, and it is not part of the Proposed Action. DOE would maintain the ability to retrieve the spent nuclear fuel and high-level radioactive waste for at least 100 years and possibly for as long as 300 years in the event of a decision to retrieve the materials to protect public health and safety or the environment or to recover constituent parts of spent nuclear fuel.

the completion of emplacement, DOE would decontaminate and close the nuclear facilities on the surface to eliminate potential radioactive material hazards. However, the Department would maintain the Waste Handling Building for the possible retrieval of waste.

Closure. For the higher-temperature operating mode, the EIS analysis assumed repository closure would begin 100 years after the start of emplacement (76 years after the completion of emplacement) and would take 10 years. Repository closure for the lower-temperature operating mode would begin 125 to 300 years after the completion of emplacement and would take between 11 and 17 years, depending on the waste package spacing. The longer time required for the lower-temperature operating mode would ensure that the repository temperature would remain below boiling after closure.

Repository closure would occur after DOE received a license amendment from the Nuclear Regulatory Commission. Closure activities would include installing the titanium drip shields and closing the subsurface facilities, decommissioning the surface facilities, sealing openings into the mountain (access ramps, ventilation shafts, boreholes), performing reclamation activities at the site, and establishing institutional controls such as permanent monuments to mark and identify the area.

S.3.1.3 Transportation

DOE would transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites around the country to the Yucca Mountain site, either by rail or by truck. The Department analyzed two transportation scenarios (*mostly legal-weight truck* and *mostly rail*) that cover the reasonably foreseeable range of transportation impacts to human health and the environment.

The mostly legal-weight truck scenario assumes that DOE would transport most of the spent nuclear fuel and high-level radioactive waste to the repository by legal-weight truck. The trucks would travel from the 77 sites to the Yucca Mountain site primarily on the U.S. Interstate Highway system, as shown in Figure S-10. An exception to this scenario would be the naval spent nuclear fuel, which the Navy would transport from the Idaho National Engineering and Environmental Laboratory to Nevada by rail, as decided in the *Record of Decision for a Dry Storage Container System for the Management of Naval Spent Nuclear Fuel.*

The mostly rail scenario assumes that DOE and the Navy would transport most of the spent nuclear fuel and high-level radioactive waste to Nevada by rail, with the exception of material from commercial nuclear generating sites that initially would not have the capability to load

NEVADA TRANSPORTATION IMPLEMENTING ALTERNATIVES

Rail corridors
- Caliente
- Carlin
- Caliente-Chalk Mountain*
- Jean
- Valley Modified

Intermodal transfer station locations and heavy-haul truck routes
- Caliente
  - – Caliente route
  - – Caliente/Chalk Mountain route*
  - – Caliente/Las Vegas route
- Sloan/Jean (one route)
- Apex-Dry Lake (one route)

* Nonpreferred

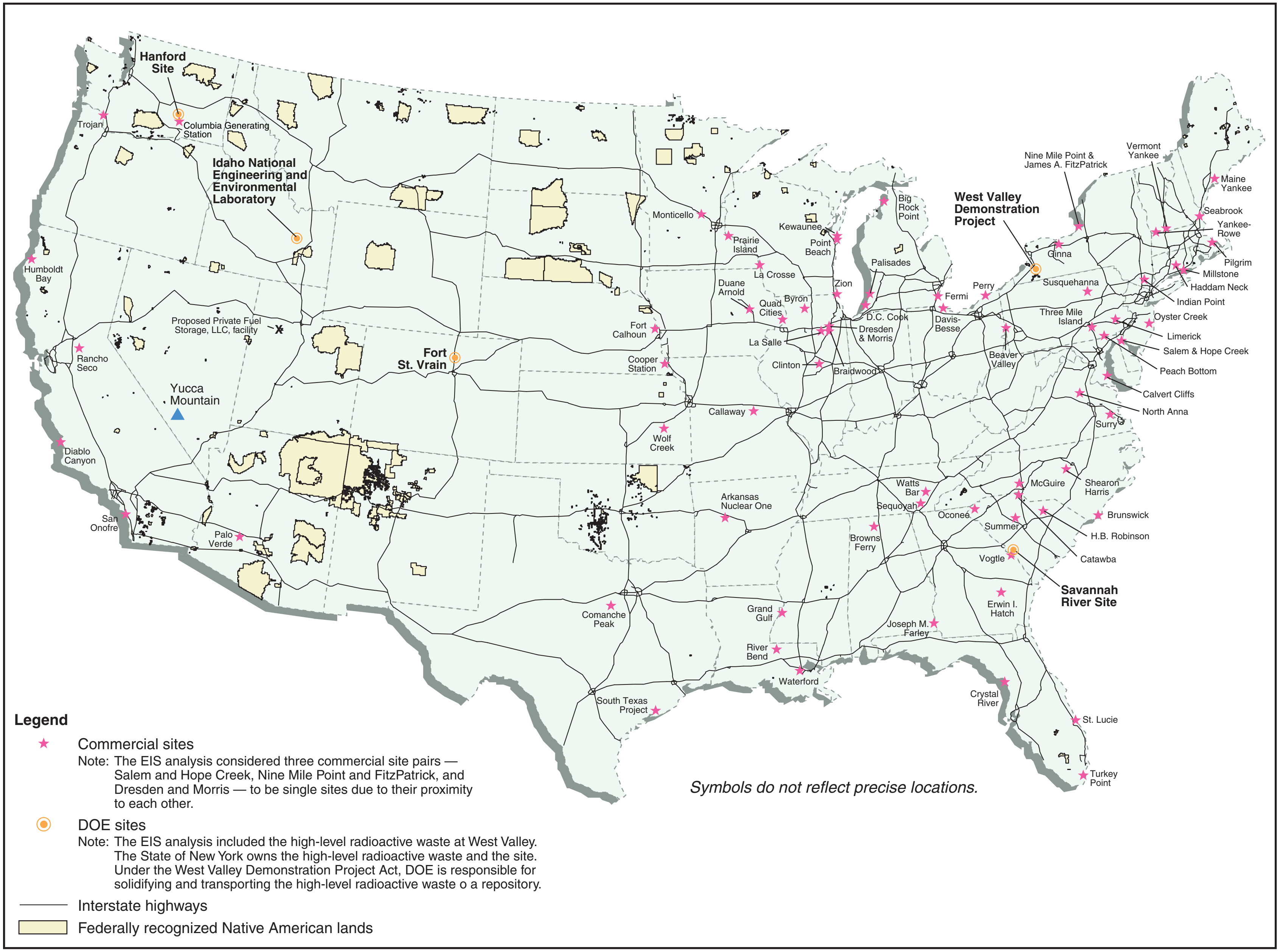

Figure S-10. Commercial and DOE sites and Yucca Mountain in relation to the U.S. Interstate Highway System.

DEFINITIONS FOR TRUCK TRANSPORTATION

Legal-weight trucks: trucks with a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), which is the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits.

Heavy-haul trucks: overweight, overdimension vehicles that must have permits from state highway authorities to use public highways.

large-capacity rail shipping casks. Those sites would use legal-weight trucks to ship material to the repository. Commercial sites with the capability to load the rail shipping casks but that did not have rail access could use heavy-haul trucks or barges to ship spent nuclear fuel to the nearest rail line. Figure S-11 shows the commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system over which the railcars could travel.

In the State of Nevada, waste that traveled from the commercial and DOE sites by legal-weight truck would continue to the repository in the same manner. Figure S-12 shows the southern Nevada highways over which the legal-weight trucks could travel. Potential routes for legal-weight truck shipments in Nevada comply with U.S. Department of Transportation regulations (49 CFR 397.101) for selecting "preferred routes" and "delivery routes" for motor carrier shipments of Highway Route-Controlled Quantities of Radioactive Materials. Based on these regulations, those shipments would arrive in Nevada on Interstate-15, travel over the planned Las Vegas Beltway, and then proceed north on U.S. Highway 95 to Yucca Mountain. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

REPOSITORY ANALYSIS

Repository Facilities and Operations
- Packaging scenarios
  - Mostly uncanistered fuel
  - Mostly canistered fuel
- Operating mode
  - Higher-temperature
  - Lower-temperature

Transportation Activities
- National transportation scenarios
  - Mostly legal-weight truck
  - Mostly rail
- Nevada transportation scenarios
  - Mostly legal-weight truck
  - Mostly rail with a new branch rail line (five corridors)
  - Mostly rail with heavy-haul truck from a new intermodal transfer station (five routes)

At this time there is no rail access to the Yucca Mountain site. This means that material traveling by rail would have to continue to the repository on a new branch rail line or transfer to heavy-haul trucks at an intermodal (that is, from rail to truck) transfer station in Nevada and then travel on existing highways that could need to be upgraded. DOE is considering implementing alternatives for the construction of either a new branch rail line or an intermodal transfer station with associated highway improvements. The Department has identified five alternatives for rail corridors, each of which has alignment variations (Figure S-13), and three alternative locations for an intermodal transfer station and five associated highway routes for heavy-haul trucks (Figure S-14). Figure S-15 shows how the national and Nevada transportation scenarios relate.

S.3.1.4 Costs

DOE estimates that the total cost of the Proposed Action, including the transportation of spent nuclear fuel and high-level radioactive waste to the repository, would be about $42.8 billion to $57.3 billion (in 2001 dollars). These costs include:

- $31.5 billion to $43.1 billion for construction and operation of the repository.
- $4.3 billion for waste acceptance, storage, and transportation.

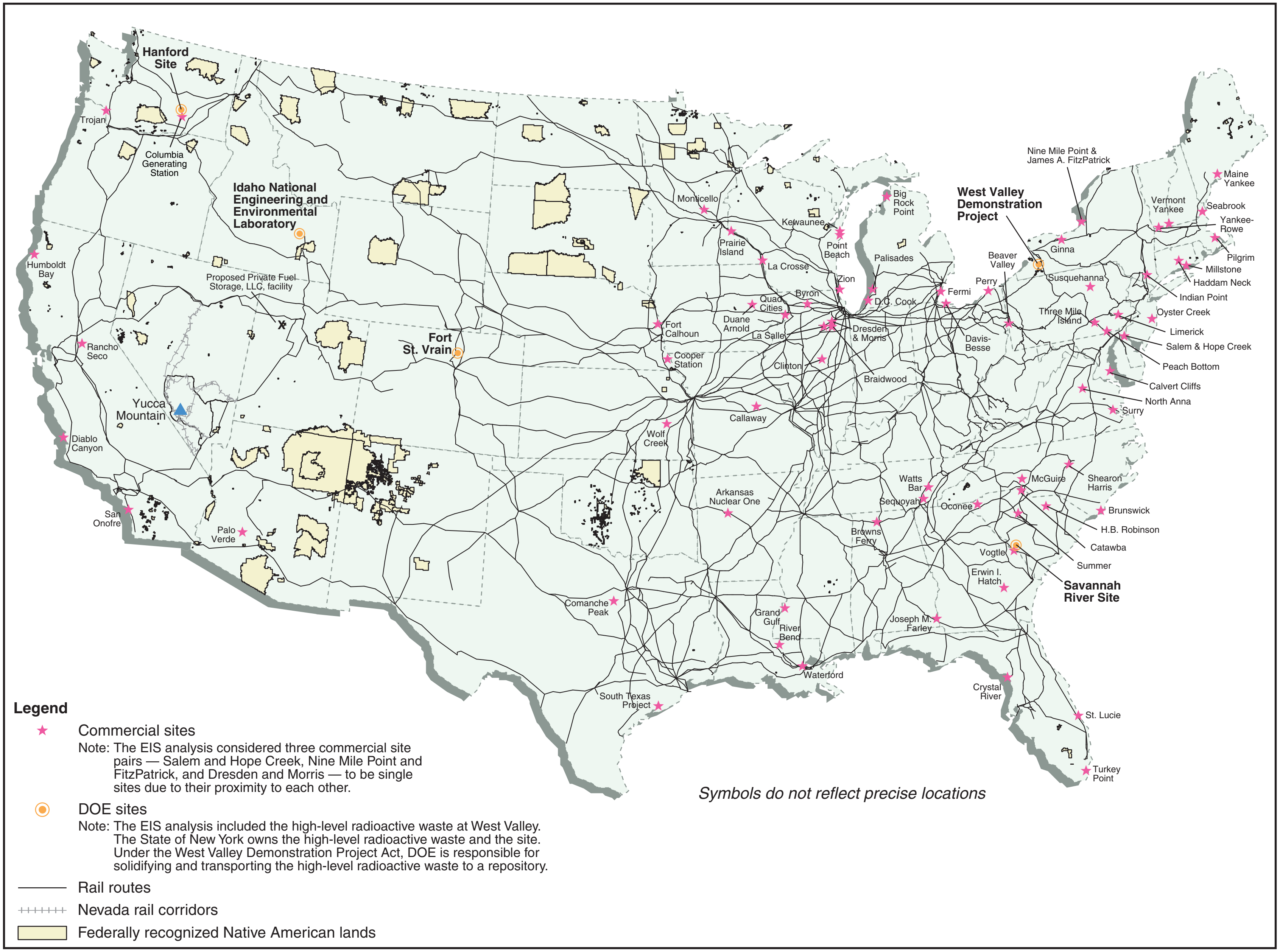

Figure S-11. Commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system.

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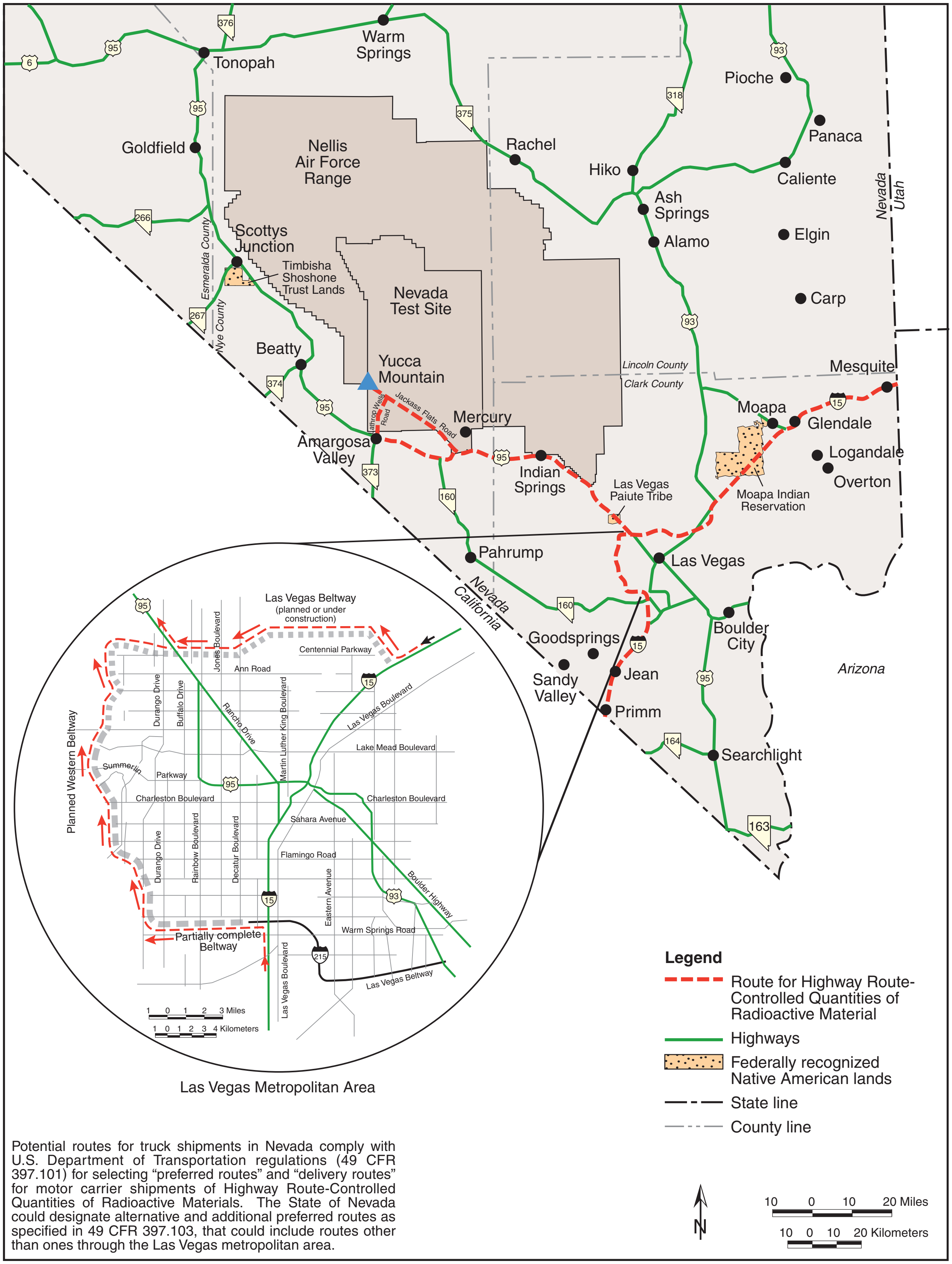

Figure S-12. Potential Nevada routes for legal-weight truck shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

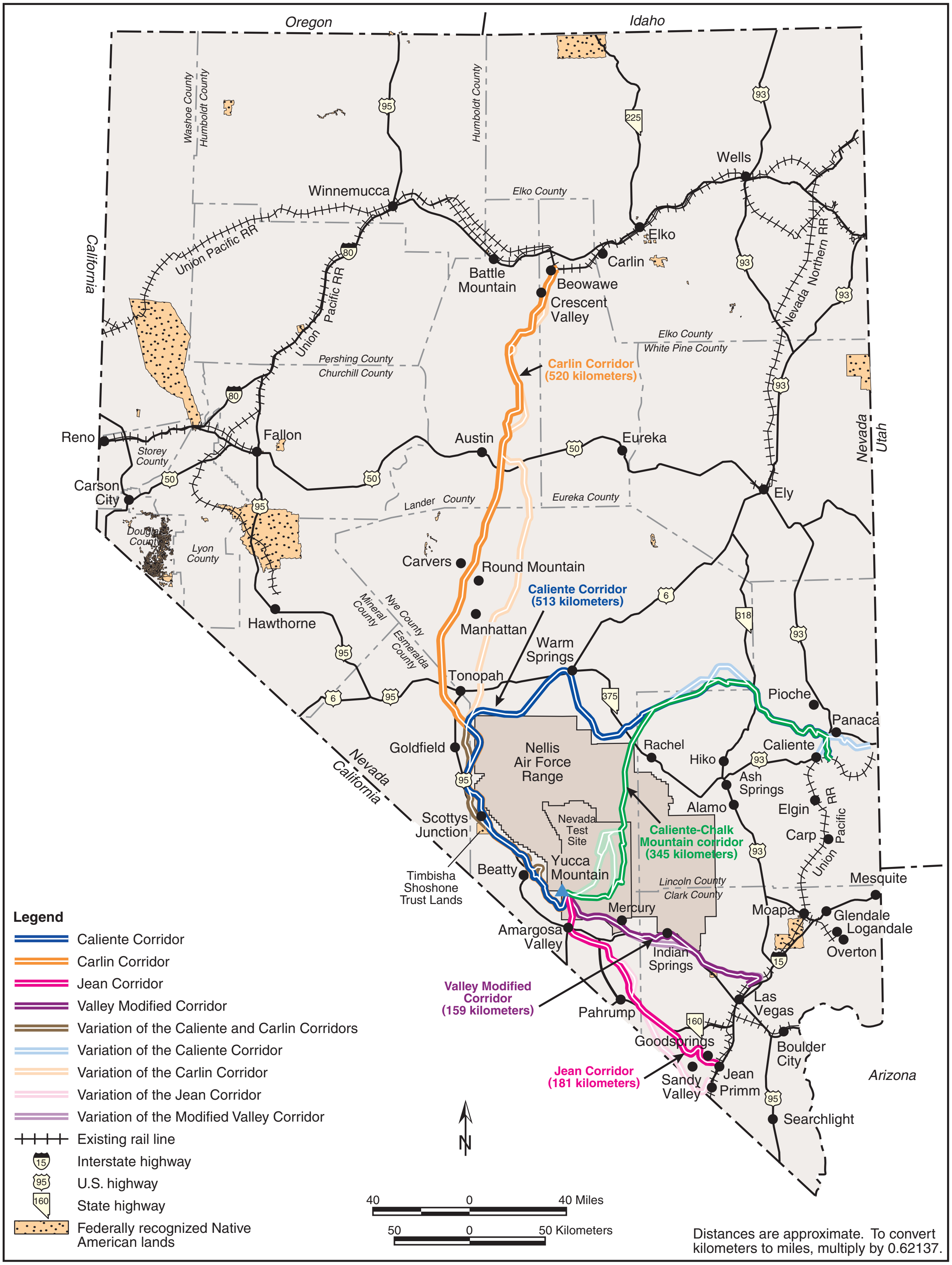

Figure S-13. Potential Nevada rail routes to Yucca Mountain.

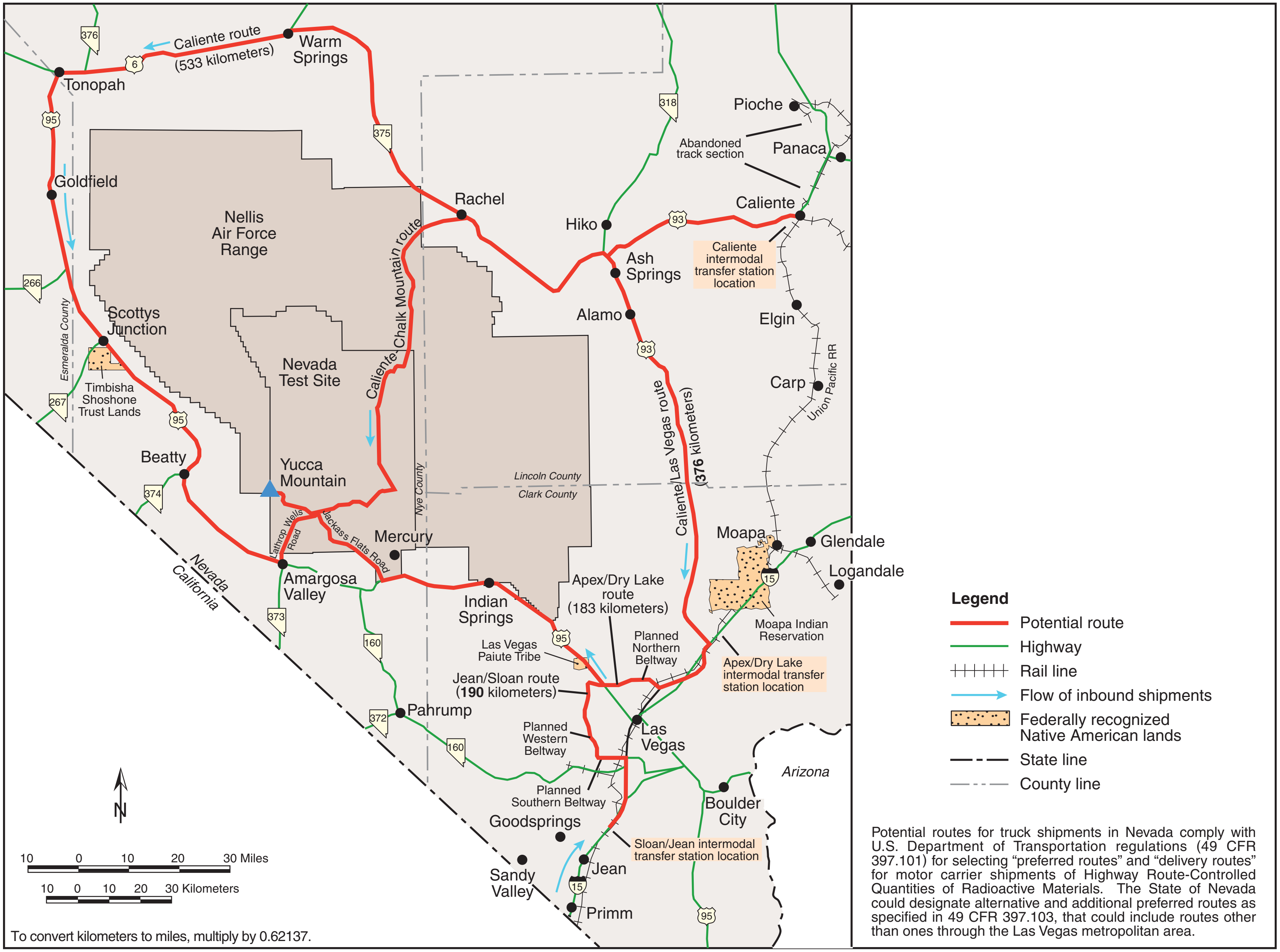

Figure S-14. Potential intermodal transfer station locations and potential routes in Nevada for heavy-haul trucks.

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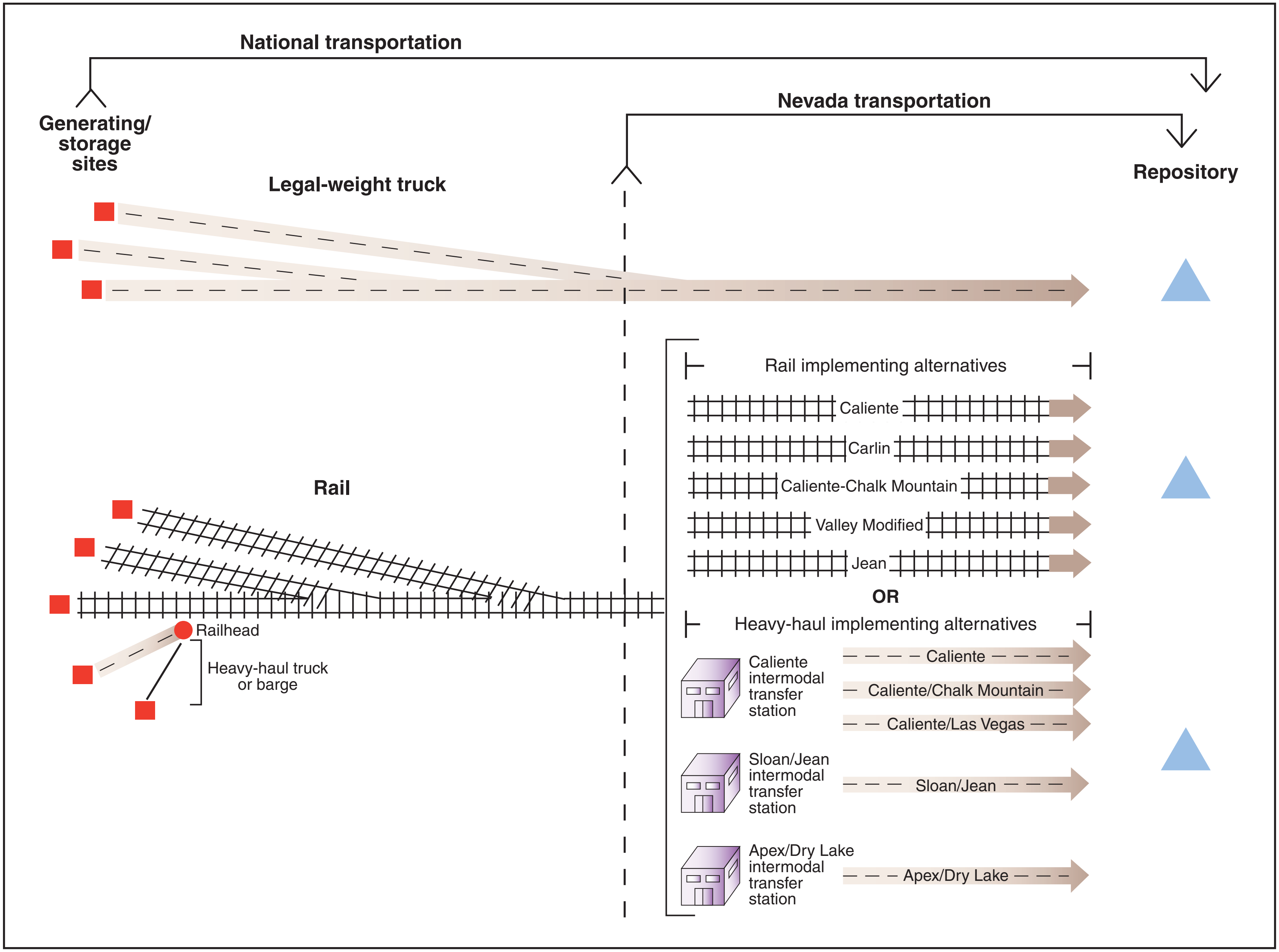

Figure S-15. Relationship of Nevada and national transportation.

- Up to $800 million for Nevada transportation, including construction of a potential branch rail line.

- $6.1 billion to $9.1 billion for program integration and institutional programs. These would include quality assurance, program management, costs associated with the Nuclear Regulatory Commission, Nuclear Waste Technical Review Board, and financial assistance for transportation planning.

The most recent estimates show that approximately 70 percent of the repository-related costs would be paid from the Nuclear Waste Fund (fees collected by nuclear utilities from ratepayers) and about 30 percent from taxpayer revenues (primarily to pay for disposal of DOE spent nuclear fuel and high-level radioactive waste).

S.3.2 NO-ACTION ALTERNATIVE

Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain and undertake site reclamation to mitigate adverse environmental impacts from those activities. The commercial nuclear power utilities and DOE would continue to store spent nuclear fuel and high-level radioactive waste. Because it would be highly speculative to attempt to predict future events, DOE decided to illustrate one set of possibilities by focusing its analysis of the No-Action Alternative on the potential impacts of two scenarios:

- Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the 72 commercial and 5 DOE sites under institutional control for at least 10,000 years.

- Scenario 2 assumes that spent nuclear fuel and high-level radioactive waste would remain at the 77 sites in perpetuity, but under institutional control for only about 100 years. This scenario assumes no effective institutional control of the stored spent nuclear fuel and high-level radioactive waste after 100 years.

> **INSTITUTIONAL CONTROL**
>
> Monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements.

DOE recognizes that neither scenario would be likely if there were a decision not to develop a repository at Yucca Mountain; however, they are part of the EIS analysis to provide a basis for comparison to the Proposed Action. There are a number of possibilities that the Nation could pursue, including continued storage of the material at its current locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository; development of new technologies; or reconsideration of other disposal alternatives to deep geologic disposal. One such centralized storage possibility, the proposed Private Fuel Storage Facility for commercial spent nuclear fuel in Utah, is currently in the Nuclear Regulatory Commission licensing process. The Commission issued a Final EIS in January 2002, however, that document was unavailable for use during the preparation of this Final EIS. The Commission has yet to issue a decision on whether to grant a license. Under any future course that would include continued storage, both commercial and DOE sites have an obligation to continue managing the spent nuclear fuel and high-level radioactive waste in a manner that protects public health and safety and the environment.

S.3.2.1 Reclamation and Decommissioning at Yucca Mountain

Under the No-Action Alternative, site characterization activities would end at Yucca Mountain. DOE would start site decommissioning and reclamation. These activities would include the removal or shutdown of all surface and subsurface facilities, and the restoration of the lands disturbed during site characterization. DOE would fill and seal drill holes to meet Nevada requirements.

S.3.2.2 Continued Storage at Commercial and DOE Sites

Under the No-Action Alternative, the 72 commercial and 5 DOE sites would continue to store spent nuclear fuel and high-level radioactive waste. For purposes of analysis, the No-Action Alternative assumes that those sites would treat and package the materials, as necessary, for their safe onsite management. It also assumes that the amount of spent nuclear fuel and high-level radioactive waste stored would be the same as that shipped under the Proposed Action (70,000 MTHM).

The EIS analysis assumed that spent nuclear fuel and high-level radioactive waste would be placed in dry-storage canisters inside reinforced concrete storage modules. Both the canister and the concrete storage module would provide shielding against the radiation that the material would emit, although the concrete module would provide the primary shielding. The dry configuration would enable outside air to circulate and remove the heat of radioactive decay. As long as spent nuclear fuel, high-level radioactive waste, canisters, and storage modules were properly maintained, this would provide safe storage.

No-Action Scenario 1. Spent nuclear fuel and high-level radioactive waste would remain in dry storage at the commercial and DOE sites and would be under institutional control for at least 10,000 years. Institutional control at these facilities would ensure the protection of workers and the public in accordance with Federal regulations. For purposes of analysis, DOE assumed that the storage facilities would undergo one major repair during the first approximately 100 years, and complete replacement after the first 100 years and every 100 years thereafter.

No-Action Scenario 2. Spent nuclear fuel and high-level radioactive waste would remain in dry storage at the commercial and DOE sites and would be under institutional control for approximately 100 years (as in Scenario 1). This scenario, however, assumes no effective institutional control after 100 years, and that the storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate after 100 years. The facilities would eventually release radioactive materials to the environment, contaminating the atmosphere, soil, surface water, and groundwater for the 10,000-year period analyzed.

The assumption for Scenario 2 that there would be no effective institutional control after approximately 100 years is based on a review of generally applicable requirements that discount altogether the consideration of institutional control after 100 years for purposes of conducting performance assessments [U.S. Environmental Protection Agency regulations (40 CFR Part 191); U.S. Nuclear Regulatory Commission regulations for disposal of low-level radioactive material (10 CFR Part 61); and the National Research Council report on standards for the proposed Yucca Mountain Repository]. Thus, in addition to its inherent conservatism, the assumption that no institutional control would be in place after 100 years provides a consistent analytical basis for comparing the No-Action Alternative and the Proposed Action.

If the institutional control period assumed for the analysis of the No-Action Scenario 2 was extended to 300 years, consistent with the lower-temperature repository operating mode of the Proposed Action, the short-term environmental impacts during the period would increase by as much as 3 times.

Figure S-16 shows conceptual timelines for activities at the commercial and DOE sites for Scenarios 1 and 2.

S.3.2.3 Costs

DOE estimates that the total cost of Scenario 1 or 2 for the first 100 years, including the decommissioning and reclamation of the Yucca Mountain site, would range from $55.7 billion to $61.3 billion (in 2001 dollars), depending on the need to replace the dry-storage canisters in addition to replacing the storage facilities during that time. If the institutional control period was extended to 300 years to be consistent

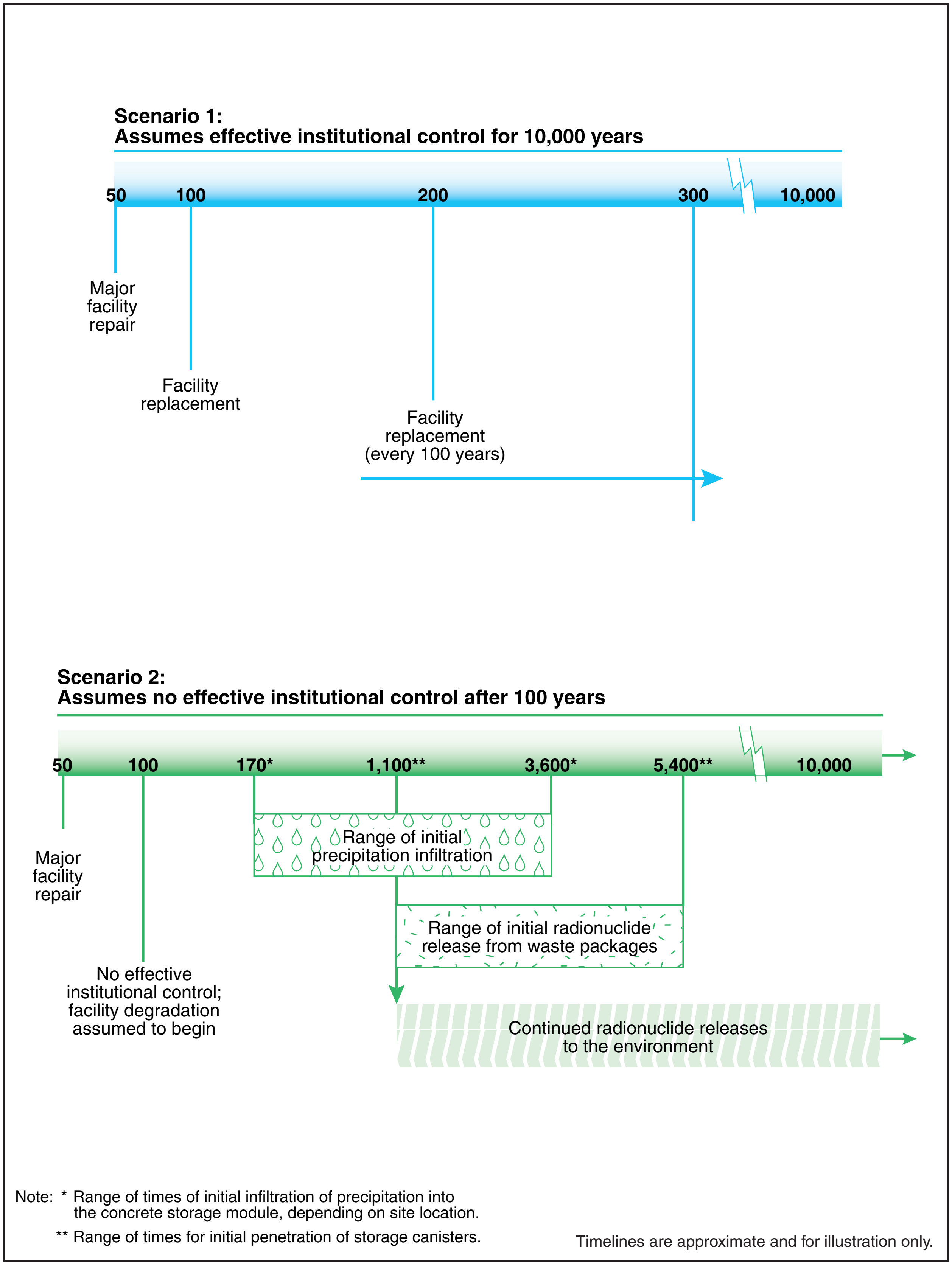

Figure S-16. Conceptual timelines for events at commercial and DOE sites for No-Action Scenarios 1 and 2.

with an extended monitoring period at the repository, the range values would triple to $167 billion to $184 billion (in 2001 dollars). The estimated cost for the remaining 9,700 to 9,900 years of Scenario 1 would range from $519 million to $572 million per year. There would be no costs under Scenario 2 after the first 100 years because that scenario assumes no effective institutional control after that time.

S.4 Issues Raised by the Public

S.4.1 Issues Raised in Public Scoping

DOE solicited written comments and held 15 public scoping meetings across the country between August 29 and October 24, 1995, to enable interested parties to present comments on the scope of this EIS.

During the public scoping process, a number of commenters asked that the EIS discuss the history of the Yucca Mountain site characterization program and requirements of the NWPA, address DOE's responsibility to begin accepting waste in 1998, describe the potential decisions that the EIS would support, and examine activities other than construction, operation and monitoring, and closure of a repository at Yucca Mountain. Other comments raised during public scoping addressed the consistency of the proposed repository with existing land uses, effects of earthquakes and volcanism, health and safety impacts, long-term impacts, and sabotage. In response to the public's input, DOE included discussions and analyses of these issues in the EIS. DOE also received comments noting that the Nation will have more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste, although the NWPA directs that the maximum amount allowed for repository disposal is 70,000 MTHM of these materials until a second repository is in operation. Commenters encouraged DOE to evaluate the disposal of the entire anticipated inventory of spent nuclear fuel and high-level radioactive waste and other waste types that might also require permanent isolation. For this reason, the EIS analyzes cumulative environmental impacts that could occur from the disposal at Yucca Mountain of the country's total projected inventory of spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. In response to other public scoping comments, DOE added an additional transportation corridor and route in Nevada to the analysis.

Many other public scoping comments presented views and concerns not related to the scope or content of the Proposed Action. Examples of these comments include statements in general support of or opposition to a repository at Yucca Mountain, geologic repositories in general, and nuclear power; lack of public confidence in the Yucca Mountain program; perceived inequities and political aspects of the siting process by which Congress selected Yucca Mountain for further study; the constitutional basis for waste disposal in Nevada; legal issues involving Native American land claims and treaty rights; and unrelated DOE activities. DOE considered and recorded these concerns, but has not included analyses of these issues in the EIS.

S.4.2 Issues Raised on the Draft EIS and the Supplement to the Draft EIS

During the public comment process for the Draft EIS and the Supplement to the Draft EIS, commenters raised a variety of key issues. DOE identified issues as "key" based on factors such as:

- The extent to which an issue concerned fundamental aspects of the Proposed Action
- The nature of the comments as characterized by the commenter
- The extent to which DOE modified the EIS in response to the issue
- The number of comments received on a particular issue

The Comment-Response Document contains the comments received on the Draft EIS and on the Supplement to the Draft EIS and the DOE responses to those comments. The following summaries illustrate some of the key issues and DOE's responses.

- *Nuclear Waste Policy Act – Why is Yucca Mountain the only site that DOE is studying?*

  The Nuclear Waste Policy Act of 1982 provided for a process for selecting sites for technical study as potential geologic repository locations. In accordance with this process, DOE identified nine candidate sites, the Secretary of Energy nominated five of the nine sites for further consideration, and DOE issued environmental assessments for the five sites. DOE recommended three of the five sites, of which Yucca Mountain was one, for possible study as candidate repository sites. In 1987, Congress amended the Nuclear Waste Policy Act of 1982, directing the Secretary of Energy to perform site characterization activities only at the Yucca Mountain site, and, if the site was found suitable, to make a determination whether to recommend that the President approve the site for development of a repository.

- *DOE's site suitability guidelines – Why did DOE change its guidelines for determining the suitability of the Yucca Mountain site?*

  The Nuclear Waste Policy Act of 1982 directed the Secretary of Energy to issue general guidelines for the recommendation of sites for characterization, in consultation with certain Federal agencies and interested governors, and with the concurrence of the Nuclear Regulatory Commission. These guidelines (issued in 1984 at 10 CFR Part 960) included factors related to the comparative advantages among candidate sites located in various geologic media, and other considerations such as population density and distribution.

  In 1987, amendments to the Nuclear Waste Policy Act specified Yucca Mountain as the only site DOE was to characterize. For this reason, DOE proposed in 1996 to clarify and focus its 10 CFR Part 960 guidelines to apply only to the Yucca Mountain site. In 1999, DOE proposed further revisions to these guidelines principally to reflect the then-proposed regulations and criteria of the Environmental Protection Agency (40 CFR Part 197) and the Nuclear Regulatory Commission (10 CFR Part 63), and to provide a technical basis to assess the performance of a geologic repository at Yucca Mountain to isolate spent nuclear fuel and high-level radioactive waste from the environment.

  In 2001, DOE promulgated its final guidelines (10 CFR Part 963), establishing the methods and criteria to determine the suitability of the Yucca Mountain site for the location of a geologic repository. The Final EIS describes these final guidelines.

- *Repository design – Why design a repository that would release radioactive materials into the environment?*

  Given the current state of technology, it is virtually impossible to design and construct a geologic repository that would provide a reasonable expectation that there would never be any releases of radioactive materials. DOE would design and construct a repository that would meet public health and safety radiation protection standards and criteria established by the EPA and the NRC. In part, the EPA standards (40 CFR Part 197) and NRC criteria (10 CFR Part 63) prescribe radiation exposure limits that the repository, based on a performance assessment, must be designed not to exceed during a 10,000-year period after closure.

  In the EIS, DOE has evaluated the environmental impacts of the proposed repository's natural and engineered barrier system, which is designed to isolate radioactive materials from the environment for thousands of years. As a result of this evaluation, DOE would not expect the repository to result in impacts to public health beyond those that could result from the prescribed radiation exposure and activity concentration limits during the 10,000-year period after closure.

- *Public participation process – Commenters stated that the public comment processes for scoping, the Draft EIS, and the Supplement to the Draft EIS were inadequate.*

  DOE's public involvement process during the development of the EIS is consistent with Council on Environmental Quality and DOE regulations implementing NEPA, and reflects DOE guidance on public participation during the preparation of EISs.

  For the scoping process and in advance of the Notice of Intent, DOE notified its stakeholders of its plans to prepare the EIS and its approach to the scoping process. When the Notice of Intent was published in the *Federal Register,* DOE mailed a series of information releases to stakeholders, sent press releases and public service announcements to the media, and provided information on the Internet and in its reading rooms. Fifteen public scoping meetings were held during a 120-day public scoping period.

  In August 1999, DOE distributed the Draft EIS to more than 3,400 stakeholders and held 21 public hearings across the Nation during a 199-day public comment period. DOE placed advertisements in local newspapers and distributed public service announcements and press releases to more than 175 local and national stakeholder and media outlets to publicize information about the Draft EIS and public comment process.

  In May 2001, DOE distributed the Supplement to the Draft EIS to more than 4,000 stakeholders and held three public hearings in Nevada during the 57-day public comment period. During this period, the Department discovered that it had inadvertently not sent the Supplement to about 700 stakeholders who had requested and received a copy of the Draft EIS. DOE acknowledged this oversight, provided copies of the Supplement to the Draft EIS, and provided a separate 45-day comment period for these stakeholders.

  In Volume III of this EIS, DOE has presented and responded to all comments on the Draft EIS and the Supplement to the Draft EIS received by August 31, 2001.

- *Need for another Draft EIS or a Supplemental EIS – The Draft EIS did not provide sufficient information or analysis and, thus, was deficient and should be withdrawn.*

  The level of information and analyses, the analytical methods and approaches used to represent conservatively the reasonably foreseeable impacts, and the use of bounding assumptions to address incomplete or unavailable information or uncertainties provide an assessment of environmental impacts consistent with all applicable requirements.

  The EIS, which DOE prepared using the best reasonably available data, analyzes a variety of implementing alternatives and scenarios. These alternatives and scenarios reflect potential repository design and operating modes, waste packaging approaches, and transportation options for shipping spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. DOE included a No-Action Alternative that analyzed two scenarios to provide a basis for comparison with the Proposed Action and to reflect the range of impacts that could occur.

  In the Draft EIS, DOE discussed ongoing site characterization activities and design evaluations, and the potential for resulting changes to repository design. Since the publication of that document, DOE improved its understanding of the interactions of potential repository features with the natural environment, and the advantages of a number of design features to enhance waste containment and isolation. DOE published the Supplement to the Draft EIS to address the most recent design enhancements, including various operating modes to manage heat generated by emplaced spent nuclear fuel and high-level radioactive waste.

This Final EIS evaluates the Proposed Action based on the design considered in the Supplement to the Draft EIS.

- *Range of alternatives – DOE should have considered a range of alternatives, such as other sites, treatment technologies, and alternatives to geologic disposal.*

  In 1980, DOE evaluated alternatives to mined geologic disposal in an EIS, and decided in 1981 in the subsequent Record of Decision to develop mined geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste. Furthermore, the NWPA provides that DOE need not consider in this EIS the need for a geologic repository and alternatives to isolating spent nuclear fuel and high-level radioactive waste in a repository. The NWPA also provides that this EIS does not have to consider any site other than Yucca Mountain for development as a repository. For these reasons, DOE did not analyze alternatives other than the Proposed Action and the No-Action Alternative.

- *The Proposed Action – DOE has failed to define its Proposed Action clearly.*

  In response to this concern, DOE has modified the EIS to promote an improved understanding of the potential environmental impacts from a more specifically defined Proposed Action. DOE has identified its preferred alternatives, simplified aspects of the Proposed Action, and modified its analyses and presentation of information to illustrate the full range of potential environmental impacts that could occur under any reasonably foreseeable repository design and operating mode or mode of transportation.

- *Preferred alternative – DOE should identify its preferred alternatives and scenarios.*

  In the Draft EIS, DOE indicated its preferred alternative was to proceed with the Proposed Action to construct, operate and monitor, and eventually close a repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. In this Final EIS, DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada.

  DOE has not identified a preference among the five candidate rail corridors in Nevada. If the Yucca Mountain site was approved, DOE would issue at some future date a Record of Decision to select a mode of transportation. If, for example, mostly rail was selected (both nationally and in Nevada), DOE would then identify a preference for one of the rail corridors in consultation with affected stakeholders, particularly the State of Nevada.

  DOE has not identified other preferences under the various scenarios presented in this Final EIS. Specific details of operating the repository and related features would be resolved only in the context of developing a License Application for review by the NRC.

- *No-Action Alternative – Why did DOE evaluate a No-Action Alternative that includes unreasonable scenarios?*

  If the Yucca Mountain site was not approved, DOE would, as required by the NWPA, prepare a report to Congress, with the Department's recommendations for further action to ensure the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. In this event, the generator sites, commercial utilities, and DOE would have to continue managing spent nuclear fuel and high-level radioactive waste in a manner that protected public health and safety and the environment. However, the future course that Congress, DOE, and the commercial utilities would take is uncertain, and a number of possibilities could be pursued.

In light of these uncertainties, DOE decided to illustrate the range of potential environmental impacts by analyzing two No-Action Alternative scenarios that could occur without additional legislation—long-term storage of spent nuclear fuel and high-level radioactive waste at the current sites with effective institutional control for at least 10,000 years, and long-term storage with no effective institutional control after about 100 years. Although the Department agrees that neither of these scenarios is likely, it selected them for analysis because they provide a basis for comparison to the impacts of the Proposed Action and because they reflect a range of the impacts that could occur.

- *Decisionmaking – DOE cannot base decisions on this EIS.*

  DOE believes that the EIS adequately analyzes the potential environmental impacts that could result from the Proposed Action. This belief is based on the level of information and analysis, the analytical methods and approaches used to represent conservatively the reasonably foreseeable impacts, and the use of bounding assumptions where information is incomplete or unavailable, or where uncertainties exist.

  For the same reasons, if the site was approved, DOE believes that the EIS provides the environmental impact information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada. However, follow-on implementing decisions, such as the selection of a specific rail alignment in a corridor, would require additional NEPA reviews.

- *Premature decisionmaking – DOE has decided to recommend the Yucca Mountain site in advance of the Final EIS and other documentation.*

  At the time DOE prepared this Final EIS, it had not made a decision on the proposed repository at Yucca Mountain. The Secretary of Energy will make a determination on whether to recommend the site to the President on the basis of a number of different types of information, including that contained in the Final EIS. Any recommendation would be accompanied not only by the Final EIS, but also by other information designated in the NWPA.

- *Population data – Why does DOE use outdated population data?*

  When DOE prepared the Draft EIS, it based the Nevada population estimates on the then-most-recently available information (1996-1997) from the U.S. Bureau of the Census. The Department used these data in its economic and demographic forecasting model to project population growth in the regions of influence and to evaluate socioeconomic impacts from the Proposed Action. For its transportation health and safety analyses, however, DOE relied on 1990 population data, which were the then-most-recent data incorporated in the standard models used for such analyses.

  In response to comments and recently available information, DOE has updated its population estimates in the regions of influence to reflect the most recent state and local information, as well as the Bureau of the Census 2000 population summary data for Nevada. To update the health and safety analyses associated with transportation in Nevada, DOE used the baseline population for each county in the region of influence and forecast the population to 2035 and scaled the impacts accordingly. To update the health and safety analyses on a national basis, DOE scaled the 1990 population-based impacts upward to reflect the relative state-by-state population growth to 2035. The projections are based on 2000 Census data.

- *Risk perception and stigma – Why didn't DOE analyze the impacts associated with the negative perceptions attached to a potential repository at Yucca Mountain?*

  During scoping for the EIS, DOE received comments saying the EIS should analyze perception-based and stigma-related impacts. Perception-based impacts would not necessarily depend on the actual physical impacts or risks from repository operations or transportation. Further, people do not consistently act in accordance with negative perceptions, and thus the connection between public perception of risk and future behavior would be uncertain or speculative at best. For these reasons, DOE determined that including analyses of perception-based and stigma-related impacts in the Draft EIS would not provide meaningful information.

  Nevertheless, in light of the comments received on the Draft EIS, DOE commissioned an examination of relevant studies and literature on perceived risk and stigmatization of communities to determine whether the state of the science in predicting future behavior, based on perceptions, had advanced sufficiently to allow DOE to quantify the impact of public risk perception on economic development or property values. Based on this examination, DOE has concluded that:

  1. While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable methods whereby such impacts could be predicted with any degree of certainty,

  2. Much of the uncertainty is irreducible, and

  3. Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

  While stigmatization of southern Nevada can be envisioned under some scenarios, it is not inevitable or numerically predictable. Any such stigmatization would likely be an aftereffect of unpredictable future events, such as serious accidents, which are not anticipated to occur. As a consequence, DOE did not attempt to quantify any potential for impacts from risk perceptions or stigma in this Final EIS.

- *Native American viewpoints – DOE did not adequately consider Native American viewpoints or incorporate these viewpoints in the analyses and resulting conclusions.*

  DOE believes that it appropriately considered Native American viewpoints by incorporating in the EIS the Native Americans' own identification of potential impacts to historic and other cultural resources important to sustaining and preserving their cultures. During the preparation of the EIS, DOE supported the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations in its preparation of a separate report, the results of which are included in the EIS.

  Based on the results of the report, DOE acknowledges in the EIS that people from many Native American tribes have used the area proposed for the repository as well as nearby lands; that the lands around the site contain cultural, animal, and plant resources important to those tribes; and that the implementation of the Proposed Action would continue restrictions on free access to the area around the repository site. Furthermore, the presence of a repository would represent an intrusion into what Native Americans consider an important cultural and spiritual area. These concerns notwithstanding, DOE and the Consolidated Group of Tribes and Organizations recognize that restrictions on public access to the area have been generally beneficial and protective of cultural resources, sacred sites, and traditional cultural properties.

- *Ruby Valley Treaty – DOE should honor the Ruby Valley Treaty of 1863 with the Western Shoshone Nation.*

  The Western Shoshone people maintain that the Ruby Valley Treaty of 1863 gives them rights to 97,000 square kilometers (37,000 square miles) in Nevada, including the Yucca Mountain region. In 1977, the Indian Claims Commission granted a final award to the Western Shoshone people, who dispute the Commission's findings and have not accepted the monetary award for the lands in question. In 1985, the Supreme Court ruled that even though the money has not been distributed, the United States has met its obligations with the Indian Claims Commission's final award and, as a consequence, the aboriginal title to the land has been extinguished.

- *Approach to environmental justice transportation analysis – DOE's two-staged assessment process masks significant impacts to minorities and low-income populations, and its failure to identify either specific locations or specific characteristics of affected communities demonstrates the inadequacy of the analysis.*

  The approach to environmental justice analysis in this EIS is consistent with the Council on Environmental Quality guidance. The goal of this approach is to identify whether any high and adverse impacts would fall disproportionately on minority and low-income populations. The approach first analyzes the potential impacts on the general population as a basis for comparison. Second, based on available information, the approach assesses whether there are unique exposure pathways, sensitivities, or cultural practices that would result in high and adverse impacts on minority and low-income populations. If high and adverse impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, no disproportionately high and adverse impacts would be expected.

  In response to comments, DOE has reevaluated available information to determine whether the Draft EIS overlooked any unique exposure pathways or unique resource uses that could create opportunities for disproportionately high and adverse impacts to minority and low-income populations. Although DOE identified additional unique pathways and resources, none revealed a potential for disproportionately high and adverse impacts.

  DOE also updated and refined information germane to its environmental justice analysis. Based on the additional information and resulting analysis, DOE has concluded that disproportionately high and adverse impacts from the construction and operation of a rail line or intermodal transfer station would be unlikely.

- *Rail and highway routes – Why didn't DOE identify the specific rail and highway routes that would be used to ship spent nuclear fuel and high-level radioactive waste?*

  Because it is impossible to predict which highway routes or rail lines DOE could use in advance of actual shipments, the Department selected potential highway routes for analysis in accordance with U.S. Department of Transportation regulations, which require the use of preferred routes (typically highways and bypasses that are part of the Interstate Highway System). The Department based its selection of potential rail routes on current rail practices, because there are no comparable Federal regulations applicable to the selection of rail routes for the shipment of radioactive materials.

In response to public comments, DOE has included maps of the representative highway routes and rail lines it used for analysis in the Final EIS. It also included potential health and safety impacts associated with shipments for each state through which shipments could pass.

- *Transportation public health and safety impacts – The transportation-related health and safety analysis was inadequate because DOE did not consider community-by-community population characteristics.*

DOE does not believe that it is necessary or appropriate to consider population characteristics on a community-by-community basis to determine potential public health and safety impacts from the transportation of spent nuclear fuel and high-level radioactive waste. The use of widely accepted analytic tools, latest reasonably available information, and cautious but reasonable assumptions if there are uncertainties, offer the most appropriate means to arrive at conservative estimates of transportation-related public health impacts.

In this EIS, DOE used computer models it has used in previous EISs and other studies. These models, such as RADTRAN 5, are widely accepted by the national and international scientific and regulatory communities.

In addition, DOE has either incorporated information that has become available since the publication of the Draft EIS or modified existing information to accommodate conditions likely to be encountered over the life of the Proposed Action. For example, in this Final EIS DOE has scaled impacts upward to reflect the relative state-by-state population growth to 2035, using 2000 Census data.

Not all aspects of incident-free transportation or accident conditions can be known with absolute certainty, and so DOE has relied on conservative assumptions that tend to overestimate impacts. For instance, DOE assumed that a hypothetical individual, the "maximally exposed individual," would be a resident living 30 meters (100 feet) from a point where all truck shipments would pass (this individual would receive a dose of about 6 millirem). Although it can be argued that individuals could live closer to these shipments, it is highly unlikely that an individual would be exposed to all shipments over the 24-year period of shipments to the repository, even though DOE incorporated this highly conservative assumption in the analysis.

In response to comments, DOE has considered locations at which individuals could reside nearer the candidate rail corridors and heavy-haul truck routes in Nevada as a way of representing conditions that could exist anywhere in potentially affected communities. For example, an individual residing as close as 4.9 meters (16 feet) to a potential heavy-haul truck route would receive an estimated dose of about 29 millirem if exposed to all shipments.

The doses from these exposures would be well below those received from natural background radiation and would not be discernible even if the doses could be measured.

- *Transportation accident conditions – Why didn't DOE analyze a range of accidents that reflect real-life conditions?*

"Real-life conditions" that would involve various types of collisions, various natural disasters, specific locations (such as mountain passes), or various infrastructure accidents (such as track failure) in effect constitute a combination of cask failure mechanisms, impact velocities, and temperature ranges, which the EIS does evaluate. Accident scenarios are modeled in this fashion to accommodate the almost infinite number of variables that any given accident could involve. In the Draft EIS, for example, DOE evaluated the ability of large aircraft components (engines and engine shafts) to penetrate shipping casks. DOE considered both small military aircraft and commercial aircraft at velocities representative of takeoffs and landings and at higher velocities. DOE found that, at lower velocities, these aircraft components would not penetrate a shipping cask sufficiently to cause a release of radioactive materials. Recent analysis of this event at higher velocities, however, indicate an increased potential for seal failure of the shipping casks. If seal failure were to occur, impacts to an urban area would be less than 1 latent cancer fatality in the exposed population.

Based on its revised analyses, DOE has concluded in the EIS that casks would continue to contain spent nuclear fuel fully in more than 99.99 percent of all accidents (of the thousands of shipments over the last 30 years, none has resulted in an injury due to release of radioactive materials). This means that of the approximately 53,000 truck shipments, there could be 66 accidents, each having less than a 0.01-percent chance that radioactive materials would be released. The chance of a rail accident that would cause a release from a cask would be even less. The corresponding chance that such an accident would occur in any particular locale would be extremely low.

- *Cask testing – Will DOE conduct full-scale testing of transportation casks?*

  The NWPA requires DOE to use casks certified by the NRC when transporting spent nuclear fuel and high-level radioactive waste to a repository. A cask's ability to survive the tests prescribed by the regulations (10 CFR Part 71) can be demonstrated either through component analysis or through scale-model and full-scale testing to demonstrate and confirm the performance of the casks. The NRC would decide which level of physical testing or analysis was appropriate for each cask design submitted.

- *Repository design – Why didn't DOE analyze the latest design in the Draft EIS?*

  In the Draft EIS, DOE evaluated a preliminary design that focused on the amount of spent nuclear fuel (and associated thermal output) that DOE would emplace per unit area of the repository (called *areal mass loading*). Areal mass loading was represented in the Draft EIS by three thermal load scenarios. The purpose of these scenarios was not to place a limit on the choices among alternative designs because, as stated in the Draft EIS, DOE expected the repository design to continue to evolve in response to ongoing site characterization and design-related evaluations. Rather, DOE selected these analytical scenarios to represent the range of foreseeable design features and operating modes, and to ensure that it considered the associated range of potential environmental impacts.

  Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes. The result of the design evolution process was the development of the *flexible design* (which the Supplement to the Draft EIS called the Science and Engineering Report Flexible Design). Although this design focuses on controlling the temperature of the rock between the waste emplacement drifts (as opposed to areal mass loading), the basic elements of the Proposed Action to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain remain unchanged since the Draft EIS.

- *Hydrologic setting – DOE lacks an understanding of the hydrologic setting and should continue to study the site and surrounding region before making any decisions.*

  DOE believes that it has sufficient information and understanding of the hydrologic setting to make an adequate determination of the potential environmental impacts from the Proposed Action. DOE, the U.S. Geological Survey, and others have been evaluating and assessing the hydrologic setting and associated characteristics at the Yucca Mountain site and nearby region for more than two decades. During this time, DOE has modified its site characterization program to reflect new information and assessments and to accommodate reviews by independent parties. Nevertheless, DOE recognizes that additional information would refine its understanding of the regional groundwater flow system, and would reduce uncertainties associated with flow and transport in the alluvial, volcanic, and carbonate aquifers.

To obtain additional information, DOE has supported Nye County in the Early Warning Drilling Program to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain as well as the relationships among the volcanic, alluvial, and carbonate aquifers. DOE also has installed a series of test wells along the groundwater flow path between the Yucca Mountain site and the Town of Amargosa Valley as part of an alluvial testing complex.

After completion of site characterization, DOE would institute a *Testing and Performance Confirmation Program*, elements of which would address the hydrologic system. The program would continue through closure of the repository.

- *Site disqualification – The Yucca Mountain site should be disqualified under 10 CFR Part 960 because subsurface fracturing would allow contaminated groundwater to reach the environment in less than 1,000 years.*

  DOE's original 1984 site suitability guidelines (10 CFR Part 960) have been superseded by Yucca Mountain-specific guidelines (10 CFR Part 963) promulgated by DOE in 2001. In any event, information and analyses do not support a finding that the site would have been disqualified under the groundwater travel time disqualifying condition at 10 CFR 960.4-2-1(d). Under that condition, a site would be disqualified if the expected groundwater travel time from the disturbed zone (the area in which properties would change from construction or heat) to the accessible environment would be less than 1,000 years along any pathway of likely and significant radionuclide travel. The definition of groundwater travel time in 10 CFR 960.2 specifies that the calculation of travel time is to be based on the average groundwater flux (rate of groundwater flow) as a summation of travel times for groundwater flow in discrete segments of the system. As a practical matter, this definition provides for consideration of the rate at which most of the water moves.

  DOE estimates that the median groundwater travel times would be about 8,000 years, and average groundwater travel times would be longer. These models indicate that small amounts of water potentially moving in "fast paths" from the repository to the accessible environment could do so in less than 1,000 years. However, the models and corroborating physical evidence indicate that most of the water would take more than 1,000 years to reach the accessible environment. Given this, DOE believes that the site would not have been disqualified under the groundwater travel condition at 10 CFR 960.4-2-1.

- *Repository performance – How can DOE possibly predict repository performance given data uncertainties, untested computer models, and the chaotic nature of the long-term processes?*

  DOE acknowledges that it is not possible to predict with absolute certainty what will occur thousands of years into the future. The NRC regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the EPA has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

  DOE has designed its performance assessment to be a combination of mathematical modeling, and natural analogs. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic, and engineered components of the disposal system. In this way, DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts over thousands of years.

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- *Disruptive natural phenomena – Commenters stated that earthquakes and volcanoes will cause releases of radioactive waste.*

  DOE has analyzed the potential public health and safety impacts that could arise from natural events such as earthquakes and volcanic activity. The disruptive natures of earthquakes and volcanic activity differ materially, both in terms of probabilities (likelihood of occurrence) and the possible disruptive nature of the events themselves. Volcanism over the long-term life of the repository, with eruptions and magma flow, would be highly unlikely, while seismic activity and its consequent ground motion would be more likely to occur.

  While the occurrence of events cannot be predicted exactly, risks can be estimated statistically. Computer simulations allow DOE to estimate risks from natural events. Thus, the EIS contains an analysis of the probabilities and effects of such events on radionuclide release, and the resultant potential human health impacts to the public.

  Although DOE would design repository structures to withstand the ground movement associated with severe earthquakes, it estimated the impacts that could result from a "beyond-design-basis" seismic event that would result in the collapse of the Waste Handling Building and consequent damage to spent nuclear fuel assemblies. DOE determined the resulting impacts associated with this scenario would be small (primarily due to the physical form of the assemblies, reduced releases due to the building rubble, and distance to the nearest population). The underground engineered barriers would be far less susceptible to damage.

  DOE also estimated the impacts of volcanic eruptions that could result in the release of volcanic ash and entrained waste into the atmosphere. DOE estimated the potential impacts on the nearest population, conservatively assuming (tending to overestimate) the direction and speed of wind transport of an ash plume, and determined that the potential for public health and safety impacts would be very small. DOE also determined that magma flows would have minimal impacts on the long-term performance of the repository.

S.4.3 Changes Made in the Final EIS

As a result of public comments and the availability of new and updated information, changes were made to the Draft EIS and Supplement to the Draft EIS and are reflected in the Final EIS. Examples of these changes are the inclusion of:

- More information regarding potential impacts, particularly impacts associated with transportation of spent nuclear fuel and high-level radioactive waste within Nevada

- Use of a "representative" fuel assembly in the accident analysis

- Use of updated data, particularly population data in the impact analyses

- A more detailed discussion of the issue of potential impacts associated with negative perceptions about the repository project

- Use of updated versions of computer models for assessing human health and transportation impacts

- Corrections or editorial changes for accuracy and clarity

- Addition of an appendix that contains general information about transportation of radioactive materials not specifically used in the analysis, but provided for public information

- Addition of the U.S. Fish and Wildlife Service Biological Opinion as an appendix to the Final EIS
- Addition of a Readers Guide to help readers understand the Final EIS

As stated in the Supplement to the Draft EIS, "The fundamental aspects of the repository have not changed." The differences in environmental impacts due to the changes noted above were minor. In most environmental resource areas, the impacts either stayed the same or were smaller than those presented in the Draft EIS or the Supplement to the Draft EIS. In those cases where the impacts were larger than previously presented (generally driven by the larger population used for analysis in the Final EIS), the increases were not materially larger.

S.5 Environmental Consequences of the Proposed Action

To analyze the potential environmental impacts associated with the Proposed Action, DOE compiled baseline information for various environmental resource areas and examined how the construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain could affect each of those environmental resources, and resulting impacts on human health. In considering the impacts on human health, DOE analyzed both routine operations and accident scenarios.

ENVIRONMENTAL CONSEQUENCES

Under the regulations implementing the procedural provisions of the National Environmental Policy Act, an EIS should include a discussion of the *environmental consequences* of the Proposed Action and alternatives. The discussion of environmental consequences must include:

- Environmental *impacts* or *effects* (impacts are synonymous with effects under the regulations)
- Any adverse environmental impacts that cannot be avoided
- The relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity
- Any irreversible or irretrievable commitment of resources

Short-term consequences are those that could occur in the period before the completion of repository closure. DOE analyzed potential short-term impacts that could occur in resource areas as a result of performance confirmation, construction, operation and monitoring, closure, and transportation activities.

Long-term consequences are those that could occur after repository closure. DOE analyzed potential long-term impacts that could occur to human health and biological resources from radiological and chemical groundwater contamination for 10,000 years after repository closure. In addition, peak dose to 1 million years was estimated.

DOE conducted a broad range of studies to obtain or evaluate the information needed for the assessment of Yucca Mountain as a geologic repository. These studies have provided in-depth knowledge about the Yucca Mountain site and vicinity and provide sufficient information to aid in DOE decisionmaking. The Department used the information from these studies in the analyses described in this EIS. However, because some of these studies are ongoing, some of the information is incomplete. Further, the complexity and variability of the natural system at Yucca Mountain, the long period evaluated (10,000 years), and incomplete information or the unavailability of some information have resulted in uncertainty

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in the analyses and findings. Throughout the EIS, DOE notes both the use of incomplete information if complete information is unavailable, and the existence of uncertainty, to enable the reader to better understand EIS findings.

The following paragraphs describe the potentially affected resources at the Yucca Mountain site and vicinity and a summary of the extent to which the Proposed Action could affect those resources.

S.5.1 YUCCA MOUNTAIN SITE AND VICINITY

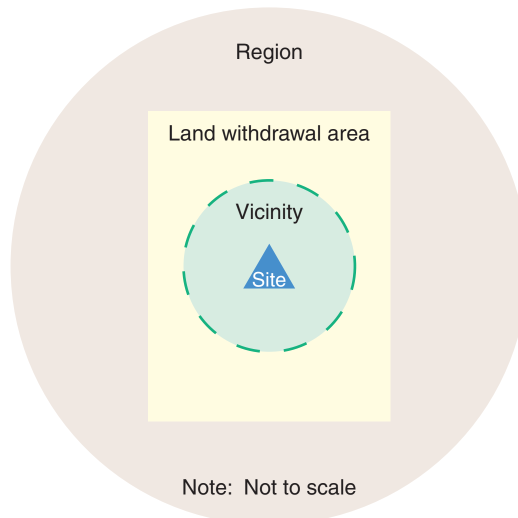
SITE-RELATED TERMS

Yucca Mountain site (the site): The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

Yucca Mountain vicinity: A general term used in nonspecific discussions about the area around the Yucca Mountain site. The EIS also uses terms such as area, proximity, etc., in a general context.

Land withdrawal area: An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Region of influence (the region): A specialized term indicating a specific area of study for each of the resource areas that DOE assessed for the EIS analyses.



Controlled Area (as defined in 40 CFR Part 197) *(not shown on illustration):* The area surrounding the repository that is restricted to public access for the long term, as identified by passive institutional controls that DOE would install at closure. The controlled area could include as much as 300 square kilometers (about 120 square miles) surface and subsurface area. It would extend no more than 5 kilometers (3 miles) in any direction from the repository footprint except in the predominant direction of groundwater flow, where the controlled area would extend no farther south than 36 degrees, 40 minutes, 13.6661 seconds North latitude, the present latitude of the southwest corner of the Nevada Test Site [about 18 kilometers (11 miles)].

The Yucca Mountain site has several characteristics that would limit or restrict possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste. The site is isolated from concentrations of human population and human activity and is likely to remain so. The climate is arid and conducive to evapotranspiration (the loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants), resulting in a relatively small volume of water that can move through the mountain, contact waste materials, and move down to the water table. The groundwater table is at least 160 meters (530 feet) below the level at which DOE would emplace spent nuclear fuel and high-level radioactive waste, providing additional separation between water sources and emplaced materials. Groundwater from Yucca Mountain flows into a closed, sparsely populated hydrogeologic basin.

The Yucca Mountain site is on Federal land in a remote area of the Mojave Desert in Nye County in southern Nevada, about 160 kilometers (100 miles) northwest of Las Vegas, Nevada. The Yucca Mountain region is sparsely populated and receives only about 170 millimeters (7 inches) of precipitation each year. The Yucca Mountain Repository land withdrawal area would occupy about 600 square kilometers (230 square miles or 150,000 acres) of land currently under the control of DOE, the Department of Defense (U.S. Air Force), and the Department of the Interior (Bureau of Land Management).

Surface repository facilities would occupy as much as 6.0 square kilometers (2.3 square miles or 1,500 acres) of the Yucca Mountain site. The remainder of the site would be used to locate support facilities, and for continued performance confirmation and testing activities (for example, wells) and to separate repository facilities from other human activities. Performance confirmation and testing activities would take place on and in the vicinity of the site. The existing environment at the site includes the structures and physical disturbances from DOE-sponsored activities that took place from 1977 to 1988 related to the selection of Yucca Mountain for site characterization, and continuing site characterization activities that began in 1989 to determine the suitability of the site for a repository.

S.5.1.1 Land Use and Ownership

The Yucca Mountain site is in the southwest corner of the DOE Nevada Test Site, partially on and adjacent to the Nellis Air Force Range. The lands in the region include Bureau of Land Management special-use areas excluded from development that would require terrain alterations, unless the alterations would benefit wildlife or public recreation. The Fish and Wildlife Service of the U.S. Department of the Interior manages the Desert National Wildlife Range and the Ash Meadows National Wildlife Refuge, which are about 50 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively. These areas provide habitat for a number of resident and migratory animal species in relatively undisturbed natural ecosystems. The National Park Service manages Death Valley National Park, which at its closest point is about 35 kilometers (22 miles) southwest of Yucca Mountain. The National Park Service also manages the small Devils Hole Protective Withdrawal in Nevada adjacent to the east-central boundary of Ash Meadows.

State-owned lands are limited in the vicinity of the proposed repository. There are scattered tracts of private land in and near communities such as Beatty and Indian Springs in Nevada. There are larger private tracts in the agricultural areas of the Las Vegas Valley, near

RUBY VALLEY TREATY ISSUE

The Western Shoshone people maintain that the Ruby Valley Treaty of 1863 gives them land rights to approximately one-third of the State of Nevada (including the Yucca Mountain region), along with portions of California, Utah, and Idaho. The Western Shoshone filed a claim in the early 1950s alleging that the Government had taken the tribe's land. The Indian Claims Commission found that Western Shoshone title to the land had gradually been extinguished, and set a monetary award as payment for the land. In 1976, the Commission entered its final award to the Western Shoshone people. The Western Shoshone dispute these findings, and have not accepted the monetary award for the lands in question. The tribe maintains that no payment has been made and that Yucca Mountain is on Western Shoshone land. Although DOE recognizes the sensitivity of this issue, a 1985 Supreme Court decision (United States v. Dann) held that the Western Shoshone claim to the land associated with the Ruby Valley Treaty has been extinguished, and that fair compensation has been made. The Supreme Court ruled that even though the monetary award has not been distributed, the United States has met its obligation and the aboriginal title to the land has been extinguished. DOE is aware that among the Native American community there is significant disagreement with the Court rulings.

Pahrump, and in the south-central portion of the large area that makes up the Amargosa Valley community. The closest year-round housing is at the location formerly known as Lathrop Wells, about 22 kilometers (14 miles) south of the site. This location is now part of the unincorporated Town of Amargosa Valley. There are farming operations about 30 kilometers (19 miles) south of the proposed repository. Figure S-17 shows the land use and ownership in the Yucca Mountain region.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. If the Yucca Mountain site was approved for development as a repository, a permanent land withdrawal would be necessary to isolate the land designated for the site from public access to satisfy Nuclear Regulatory Commission licensing requirements. The EIS analysis assumed the use of an area of approximately 600 square kilometers (150,000 acres) on Bureau of Land Management, U.S. Air Force, and DOE lands in the vicinity of the proposed repository. Figure S-18 shows the land withdrawal area that DOE used for analytical purposes. Proposed Action activities would require the use of as much as about 6.0 square kilometers (1,500 acres) of noncontiguous areas within the 600-square-kilometer (150,000-acre) area. These activities would not conflict with land uses on adjacent lands.

S.5.1.2 Air Quality

The evaluation of air quality impacts considered potential atmospheric releases of nonradiological pollutants and radiation doses from releases of radionuclides at the Yucca Mountain site. Nonradiological pollutant air concentrations were evaluated at the location of the maximally exposed individual member of the public and compared to National Ambient Air Quality Standards for criteria pollutants. Radiation doses were estimated for the maximally exposed individuals and populations of the public and workers.

Nonradiological Impacts. Principal nonradiological pollutants evaluated are the criteria pollutants nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with a diameter less than 10 micrometers (PM_{10}). Emission of the gases nitrogen dioxide, sulfur dioxide, and carbon monoxide comes primarily from fuel combustion by vehicles, construction equipment, and boilers. PM_{10} is released mainly as a component of fugitive dust from land and excavation activities, as well as in smaller quantities from fuel combustion.

Exposures of the maximally exposed individual to airborne pollutants would be a small fraction of National Ambient Air Quality Standards. The highest concentrations of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, and carbon monoxide) would be less than 1 percent of standards in all cases. Concentrations of PM_{10} were estimated to be relatively higher, less than 6 percent of the 24-hour limit and less than 2 percent of the annual limit during some project phases. These PM_{10} concentrations were estimated without considering common fugitive dust suppression measures, so actual concentrations would likely be lower.

The proposed site of the Yucca Mountain repository is in an area considered by the Environmental Protection Agency to be in attainment with Clean Air Act requirements. Therefore, Clean Air Act general conformity requirements do not apply to activities at the Yucca Mountain site.

Radiological Impacts. Radiological air quality impacts were evaluated as the radiation doses that could occur from airborne releases of radionuclides. The primary radionuclide released from Yucca Mountain would be naturally occurring radon-222 and its radioactive decay products. Releases of very small quantities of manmade radionuclides (krypton-85 and other noble gases) would occur only during the operations period, when spent nuclear fuel assemblies would be removed from transportation casks in the Waste Handling Building.

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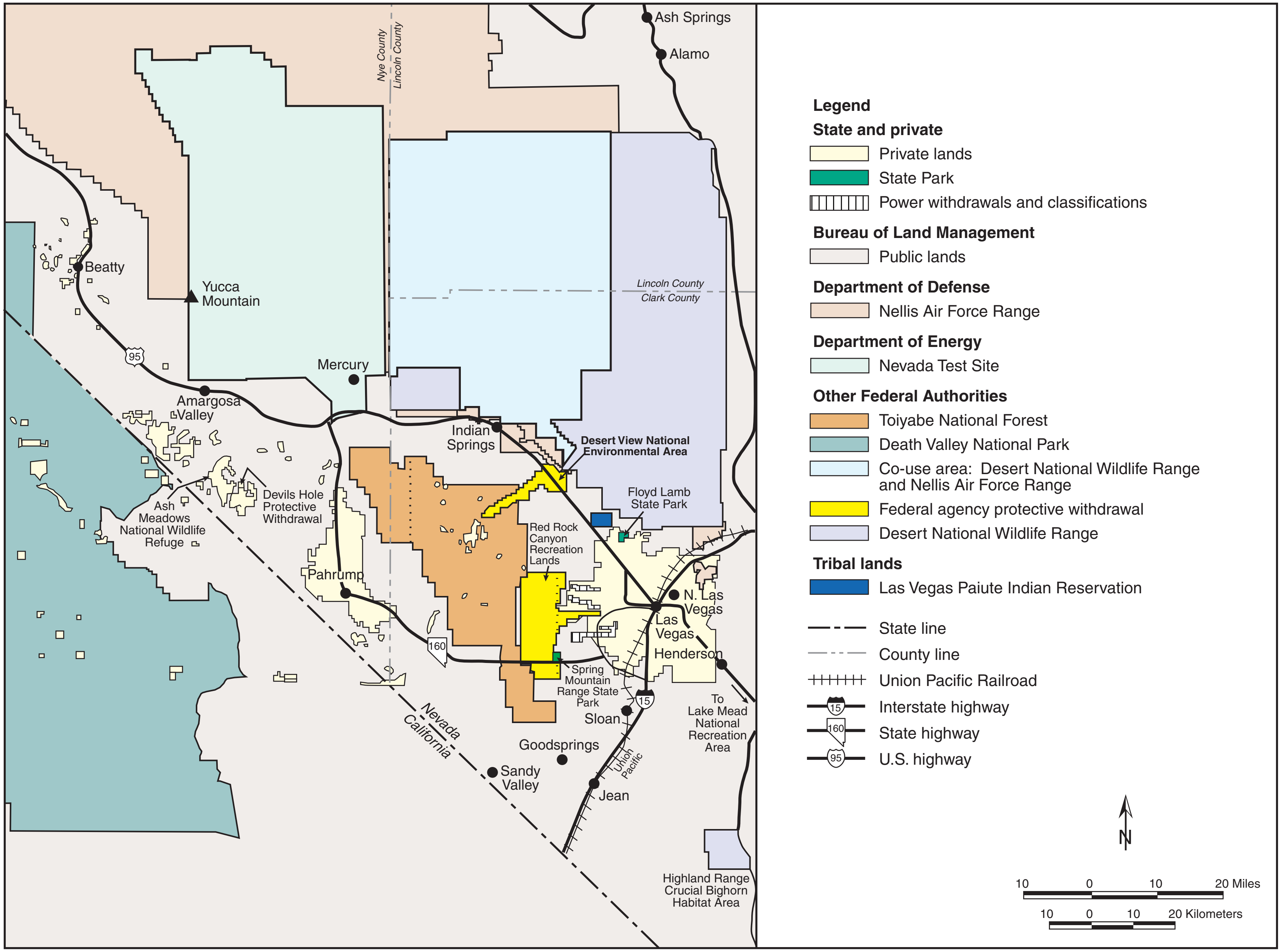

Figure S-17. Land use and ownership in the Yucca Mountain region.

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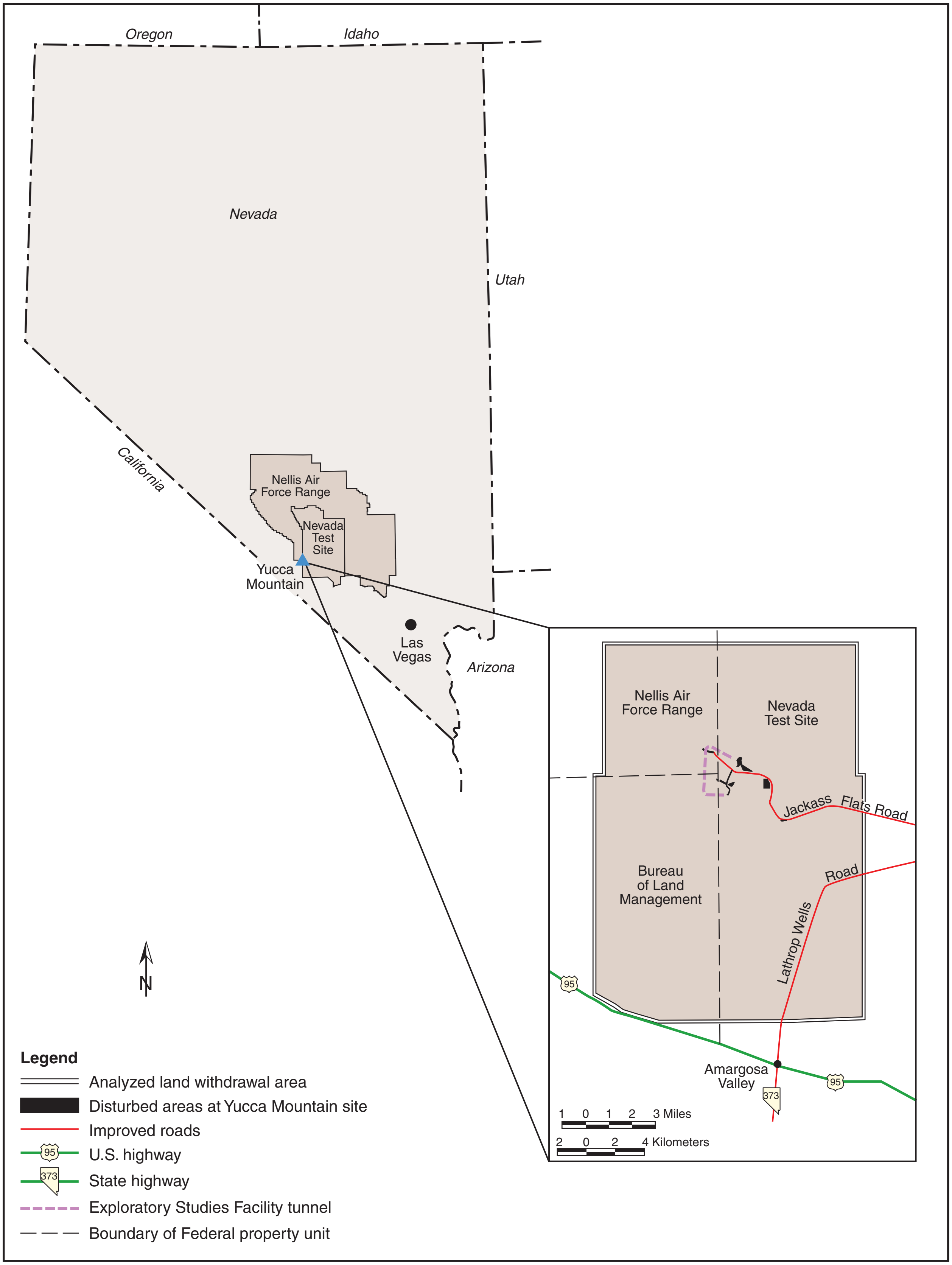

Figure S-18. Land withdrawal area used for analytical purposes.

RADIATION

In the United States, people are inevitably exposed to three sources of ionizing radiation: natural sources unaffected by human activities, such as cosmic radiation from space and natural radiation in the ground (for example, that from radon); sources of natural origin but affected by human activities, such as air travel and tunneling through rocks as at Yucca Mountain; and manmade sources, such as medical X-rays and consumer products. In the Yucca Mountain region, individuals are typically exposed to a 340- to 390-millirem radiation dose from natural and manmade sources each year, compared to about 300 millirem for the average person living in other areas of the United States.

When a person is exposed to ionizing radiation, the amount absorbed by the body is called the radiation *dose*. Dose is often described in measurement units of *rem*, which take into account how different types of radiation affect the body (the biological effectiveness). Small doses are described in *millirem*, each of which is one one-thousandth of a rem.

To analyze the short-term impact of exposure to radiation, DOE used a *maximally exposed individual* (member of the public, involved worker, or noninvolved worker), defined as the individual whose location and habits result in the highest potential total radiation dose from a particular source for all exposure routes (inhalation, ingestion, direct exposure). For long-term impacts, DOE used a *reasonably maximally exposed individual* (member of the public), defined as a hypothetical individual whose location and habits would place this individual among those with the highest total radiological or chemical exposure (and thus dose) from a particular source for all exposure routes (for example, inhalation, ingestion, direct exposure).

The maximum annual dose to the maximally exposed individual member of the public would range from about 0.73 millirem per year to 1.3 millirem per year, depending on the operating mode. The range in dose is due primarily to the varying size of the repository, with a larger repository having higher radon release and resulting in higher dose. Greater than 99.99 percent of the annual dose would be from radon-222 and radon decay products. The preclosure Public Health and Environmental Standard found at 10 CFR 63.204 is 15 millirem per year to a member of the public. Maximum annual doses from repository activities would range from about 5 to 9 percent of this standard. The average individual in the United States receives 200 millirem per year from exposure to naturally occurring radon and its decay products, so Yucca Mountain releases would be expected to add less than 0.7 percent to the natural background dose from radon.

Radiation doses from radionuclides released to air were also estimated for the general population within 80 kilometers (50 miles) of the site, the maximally exposed noninvolved worker, and the noninvolved worker population at Yucca Mountain. There are no applicable air quality standards for these exposure groups and individuals. However, these radiation doses are used to estimate the potential human health impacts presented in Section S.4.1.7. Estimates of health impacts to members of the public are converted directly from these air quality dose estimates. The doses to noninvolved workers from airborne exposures would be very small compared to other occupational doses; therefore, the doses estimated here would contribute minimally to the estimates of health impacts to noninvolved workers presented in Section S.4.1.8.

S.5.1.3 Geology

Yucca Mountain originated from volcanism and faulting that occurred 14 million to 11.5 million years ago. The mountain is bordered on the north by Pinnacles Ridge and Beatty Wash, on the west by Crater Flat, on the south by the Amargosa Desert, and on the east by the Calico Hills and by Jackass Flats, which contains Fortymile Wash. Beatty Wash is one of the largest tributaries of the Amargosa River and drains the region north and west of Pinnacles Ridge, a part of Yucca Mountain that is north of the proposed repository. Fortymile Wash is the most prominent drainage through Jackass Flats to the Amargosa River. The river is dry along most of its length most of the time. Figure S-19 shows the physiographic subdivisions and characteristic land forms in the region of influence for geology.

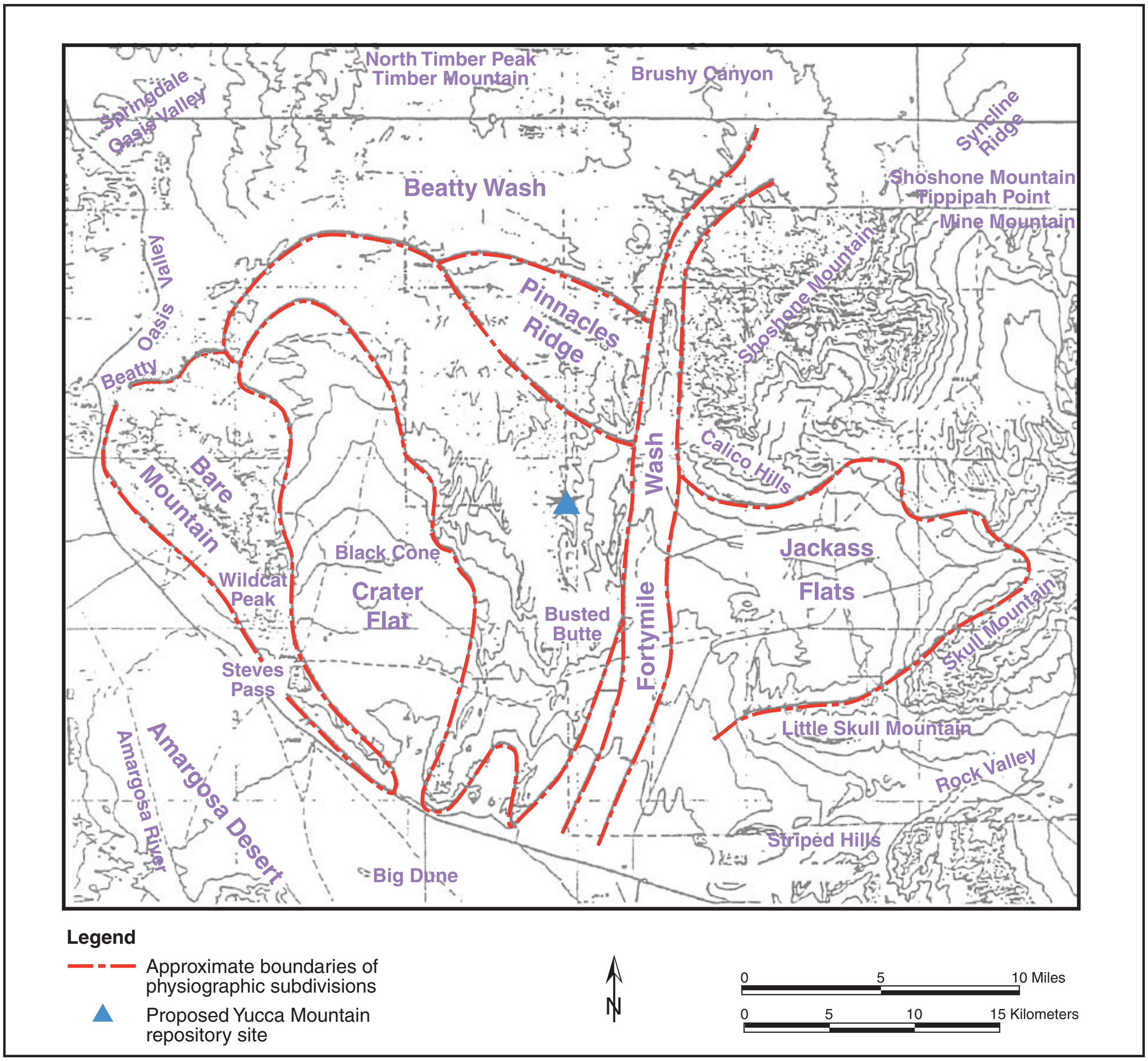

Figure S-19. Physiographic subdivisions of the Yucca Mountain area.

DOE would build the proposed repository and emplace the waste packages in a mass of volcanic rock (welded tuff) known as the Topopah Spring Tuff. This formation was formed by a volcanic ash-flow from the calderas north of Yucca Mountain 12.8 million years ago and has not been disturbed by volcanic activity since then. The volcanic activity that produced these rocks is complete and, based on the geology of similar volcanic systems in the region, additional silicic volcanic activity would be unlikely. (Younger, small-volume basaltic volcanoes to the south, west, and northwest of Yucca Mountain have been the focus of extensive study by DOE.) DOE chose the Topopah Spring Tuff as the potential repository emplacement area because of (1) its depth below the ground surface that would protect nuclear materials

VOLCANISM

Differing views on the risks of volcanism near Yucca Mountain result from uncertainty in the volcanic hazard assessment. To address these uncertainties, DOE has DELETION conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts. In 1995 and 1996, DOE convened a panel of recognized experts representing other Federal agencies (for example, the U.S. Geological Survey and national laboratories) and universities (for example, the University of Nevada and Stanford University) to assess uncertainties associated with the data and models used to evaluate the potential for disruption of the proposed Yucca Mountain Repository by a volcanic intrusion. The panel estimated that the chance of a volcanic disruption at or near the repository during the first 10,000 years after closure would be 1 in 7,000.

from exposure to the environment, (2) its extent and characteristics that would enable the construction of stable openings and the accommodation of a range of temperatures, (3) its location away from major faults that could adversely affect the stability of underground openings and could provide pathways for water flow, eventually leading to radionuclide release, and (4) its location well above the present water table.

North-trending seismic faults are the characteristic geological structural elements at Yucca Mountain. The Solitario Canyon Fault along the west side of Yucca Mountain and the Bow Ridge Fault along the east side are the major block-bounding faults that bracket the area under consideration for the proposed repository. The proposed repository has been configured such that there would be no block-bounding faults in the emplacement zone. Between the major north-trending, block-bounding faults there are intrablock or subsidiary faults. One intrablock fault, called the Ghost Dance Fault, is in the area of the proposed repository and one relatively short, northwest-trending subsidiary fault, the Sundance Fault, transects the area of the proposed repository. Studies at Yucca Mountain indicate that individual faults have very long recurrence intervals between the types of earthquakes that would be powerful enough to cause surface displacements. Strain can accumulate on these faults over long periods between surface-rupturing earthquakes. Little or no seismic activity might occur during this long strain buildup.

EARTHQUAKES

Experts have evaluated site data and other relevant information to assess where and how often future earthquakes could occur, how large they could be, how much offset could occur at the Earth's surface, and how much ground motion could diminish with distance. DOE would design the repository to withstand the effects of earthquakes that might reasonably occur in the future.

DOE has monitored seismic activity at the Nevada Test Site since 1978. In 1992, an earthquake measuring 5.6 on the Richter scale occurred at Little Skull Mountain, about 20 kilometers (12 miles) southeast of Yucca Mountain. It caused no detectable damage in tunnels or characterization facilities at the Yucca Mountain site, but did cause some minor damage at the Field Office Center in Jackass Flats about 5 kilometers (3 miles) north of the epicenter.

S.5.1.4 Hydrology

Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin, which is within the larger Death Valley Regional Groundwater Flow System). This area is characterized by a very dry climate, limited surface water, and generally deep aquifers. The Death Valley basin is a closed hydrologic basin, which means its surface water and groundwater can leave only by evaporation from the soil and other surfaces and transpiration from plants. Surface-water resources include drainages and streambeds, streams, springs, and playa lakes. The groundwater system includes recharge zones (where water infiltrates from the surface and reaches the saturated zone and aquifers), discharge points (where groundwater reaches the surface), unsaturated zones (above the water table), saturated zones (below the water table), and aquifers (water-bearing layers of rock that can provide water in usable quantities).

Surface Water. Yucca Mountain and the Death Valley Basin, like other areas in the southern Great Basin, generally lack perennial streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas. Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry along most of their lengths most of the time.

Activities associated with the Proposed Action could cause minor impacts to surface hydrology at the Yucca Mountain site. The potential for contaminants to reach surface water generally would be limited to spills or leaks followed by a rare precipitation or snow melt event large enough to generate runoff. The most likely sources of potential surface-water contaminants would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Because these materials would be used and stored inside buildings or appropriate containment structures and managed in accordance with standard best management practices, there would be little potential for contamination to spread to surface water.

Disturbing the land surface probably would alter the rate at which water could infiltrate the surface. Of the approximately 4.3 to 6.0 square kilometers (1.7 to 2.3 square miles or 1,060 to 1,500 acres) needed for surface repository facilities, construction and operation and monitoring activities probably would disturb about 2.8 to 4.5 square kilometers (690 to 1,100 acres). The amount of newly disturbed land would vary depending on the operating mode used. The high end of the range would be attributed to the lower-temperature operating mode with maximum waste package spacing and surface aging. However, DOE expects the resulting change in the amount of runoff actually reaching the drainage channels to be relatively minor because repository activities would disturb a relatively small amount of the natural drainage area. The eventual removal of structures and impermeable surfaces, with mitigation (soil reclamation) and rehabilitation of natural plants in disturbed areas, would decrease runoff from these areas.

Facilities at which DOE would manage radioactive materials would be able to withstand the probable maximum flood (the most severe flood that is reasonably foreseeable). The foundations would be built up as necessary so the facilities would be above the flood level. Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. The water levels expected from a 100-year, 500-year, or probable maximum flood would be unlikely to reach the North or South Portal entrances to the subsurface facilities, but some of the support facilities outside the North Portal would be within the level of the probable maximum flood. Access routes to the North Portal Operations Area and the South Portal Development Area would cross the lower magnitude flood areas as well.

Portions of the transportation system probably would be in the 100-year floodplains of Midway Valley Wash, Drillhole Wash, Busted Butte Wash, and/or Fortymile Wash. Structures that might be constructed in a floodplain could include one or more bridges to span the washes, one or more roads that could pass through the washes, or a combination of roads and culverts in the washes. Based on an initial assessment, potential impacts from such activities would be minor.

Groundwater. The groundwater flow system of the Death Valley region is very complex, involving many groundwater basins, as shown in Figure S-20. Over distance, aquifers and confining units in the groundwater flow system vary in their characteristics or even their presence. In some areas, confining units allow considerable movement between aquifers; in other areas confining units are sufficiently tight to support artesian conditions (where water in a lower aquifer is under pressure in relation to water in an overlying aquifer).

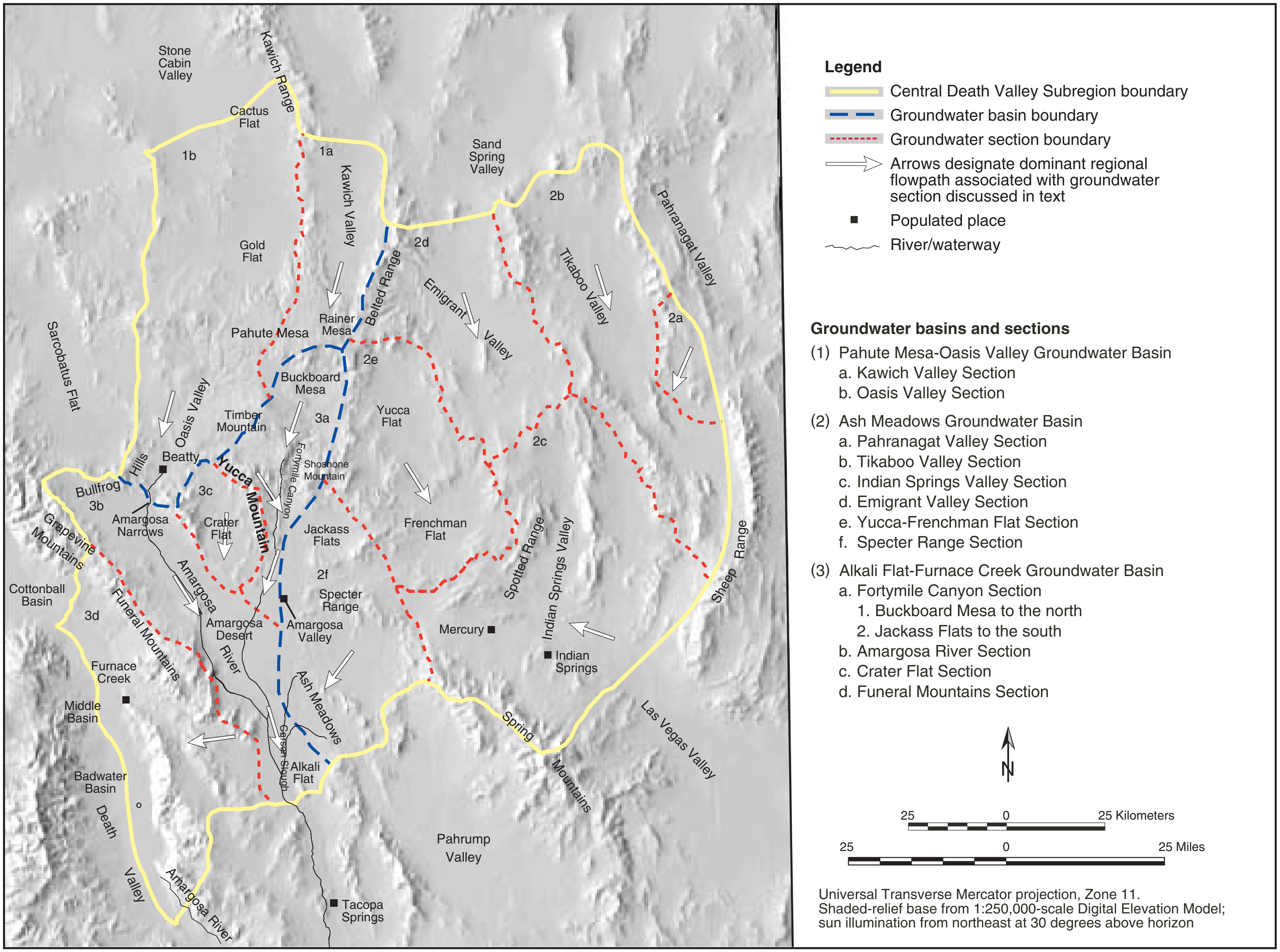

Figure S-20. Groundwater basins in the Yucca Mountain vicinity.

> **GROUNDWATER**
>
> **Aquifer:** A subsurface saturated rock unit of sufficient permeability to transmit groundwater and capable of yielding usable quantities of water to wells and springs.
>
> **Confining unit:** A rock or sediment layer that restricts the movement of water into or out of adjacent aquifers.
>
> **Spring:** A point (sometimes a small area) through which groundwater emerges from an aquifer to the ground surface.

Groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley. This broad area is called the Death Valley regional groundwater flow system. The area around Yucca Mountain is in the central subregion of the Death Valley regional groundwater flow system, which has three groundwater basins: (1) Pahute Mesa-Oasis Valley, (2) Ash Meadows, and (3) Alkali Flat-Furnace Creek.

There is scientific uncertainty about the exact locations of the groundwater flow boundaries between the three groundwater basins in the central Death Valley subregion. All interpretations of the available data, however, place the aquifers below Yucca Mountain in the central Alkali Flat-Furnace Creek groundwater basin. In the region of influence for hydrology, the primary sources of groundwater recharge are infiltration on Pahute Mesa, Rainier Mesa, Timber Mountain, and Shoshone Mountain to the north, and the Grapevine and Funeral Mountains to the south. Recharge in the immediate Yucca Mountain vicinity is small in comparison and consists of water reaching Fortymile Wash as well as precipitation that infiltrates the surface. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres), assuming 4.7 millimeters (0.2 inch) of infiltration per year, would be about 0.2 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

To pose a threat to groundwater during the construction, operation and monitoring, or closure phase of the Proposed Action, a contaminant such as a hazardous material would have to be spilled or released and then carried down either by its own weight or by infiltrating water. The depth to groundwater [at least 160 meters (530 feet)] and the arid environment would combine to reduce the potential for contaminant migration during the preclosure period of repository operations.

The most likely way to affect infiltration rates and, thus, groundwater recharge would be as the result of a land disturbance that caused additional runoff from the facilities to accumulate in areas like Fortymile Wash. That is, the additional runoff could increase groundwater recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small. After closure, the implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions.

DOE would meet the water demand for the Proposed Action by pumping from the groundwater in the Jackass Flats area. Estimates of perennial yield of the aquifer (the quantity of groundwater that can be withdrawn annually without depleting the reservoir, also referred to as safe yield) in the Jackass Flats area ranges from 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet). The highest demand during the repository construction phase and the operation and monitoring phase [as high as 360,000 cubic meters (290 acre-feet) per year], added to the demand from ongoing Nevada Test Site activities, would be below the lowest estimate of the area's perennial yield.

Maximum repository water demands would occur during emplacement and development activities and, when combined with the baseline demands from Nevada Test Site activities, would approach (but still be below) the lowest perennial yield estimate. None of the water demand estimates would approach the high estimates of perennial yield.

S.5.1.5 Biological Resources and Soils

The plants and animals in the Yucca Mountain vicinity are typical of species in the Mojave and Great Basin Deserts. No plants listed as *threatened* or *endangered*, that are proposed for listing, or that are candidate species under the Endangered Species Act occur in the land withdrawal area analyzed in this EIS. No plant species classified as *sensitive* by the Bureau of Land Management are known to occur in the analyzed land withdrawal area. Several species of cacti and yucca protected from commercial collection by the State of Nevada occur throughout the Yucca Mountain region, including the analyzed land withdrawal area. Neither the removal of vegetation from the area required for the repository nor the impacts to some species would affect regional biological diversity and ecosystem function. Repository construction activities in areas of undisturbed vegetation could result in additional areas where colonization by exotic (non-native) plant species could occur. Reclamation would enhance the recovery of native vegetation in disturbed areas and reduce colonization by exotic species.

One animal species that lives at the Yucca Mountain site, the desert tortoise, is listed as *threatened* under the Endangered Species Act. Yucca Mountain is at the northern edge of the range of the desert tortoise, and the presence of tortoises at the site is infrequent in comparison to other portions of its range. DOE anticipates that the deaths of small numbers of individual tortoises from vehicle traffic and activities could occur during the repository construction, operation and monitoring, and closure phases. Although these losses would cause a small decrease in the abundance of desert tortoises in the immediate vicinity of the repository site, they would not affect long-term survival of the local or regional population of the species. DOE would continue to work with the Fish and Wildlife Service and would implement the terms and conditions established by the Service in its Biological Opinion to minimize impacts to desert tortoises at the site. There is no critical habitat in the analyzed land withdrawal area.

Five animal species classified as *sensitive* by the Bureau of Land Management (two bats, a lizard, an owl, and a beetle) occur at the Yucca Mountain site. These species are unlikely to be affected by repository activities because loss of individuals would be rare or a small amount of habitat would be disturbed, depending on the species.

There would be small quantities of routine releases of radioactive materials from the repository during the preclosure period. These releases would consist of gases, principally naturally occurring radon, and krypton from spent nuclear fuel handling. The small quantities released would result in small doses to plants and animals as the gases dispersed in the atmosphere. The estimated doses would be unlikely to cause measurable detrimental effects in populations of even the more radiosensitive species in terrestrial ecosystems.

There are no naturally occurring wetlands on the proposed repository site, so no impacts to such areas would occur as a result of repository construction, operation and monitoring, or closure. Soils at the site are from underlying volcanic rocks and mixed alluvium (sand, silt, or clay deposited on land by water) dominated by volcanic material, and in general have low water-holding capabilities. The potential for soil impacts such as erosion would increase slightly as a result of land-disturbing activities at the site, but DOE would use erosion control techniques to minimize impacts.

DOE also considered whether, during the postclosure period, the repository would affect biological resources at Yucca Mountain on the repository footprint through the heating of the ground surface and through radiation exposure to species from contaminant migration through groundwater to discharge points. After closure under the higher-temperature operating mode, heat from the decay of radionuclides in the waste would cause temperatures in the rock near the disposal containers to rise above the boiling point of water. The time that the subsurface temperature could remain above the boiling point would vary up to a few thousand years. Conduction and the flow of heated air and water through the rock would carry the heat away from the waste packages through the rock. The heat would spread to the surface above and to the aquifer below.

Although the atmosphere would remove excess heat when it reached the ground surface, the temperature of near-surface soils could increase slightly. As reported in the Draft EIS for the hotter, high thermal load scenario, surface soil temperatures were estimated to increase by as much as approximately 3°C (5.4°F) in dry soil at a depth of 1 meter (3.3 feet), which could affect root growth and the growth of microbes or nutrient availability. The range of repository operating modes now being considered would provide a cooler repository than the high thermal load analyzed in the Draft EIS, so any soil temperature increases would be less than those cited above. Potential impacts from the repository on biological resources could consist of an increase of heat-tolerant species and a decrease of less heat-tolerant species. In general, areas affected by repository heating could experience a loss of shrub species and an increase in annual species. A shift in the plant community could also lead to localized changes in the animal community that depends on the plant community for food and shelter. The effects of repository heat on the surface soil temperatures would gradually decline with distance from the repository out to about 500 meters (1,640 feet). DOE expects any shift in species composition to be limited to that general area.

In the distant future (many thousands of years) groundwater would contain small quantities of radionuclides and chemically toxic substances. Doses to humans from exposure to this water would be very small; doses to plants and animals would be even smaller, and unlikely to have adverse impacts on the population of any species.

Impacts to surface soils at Yucca Mountain in the postclosure period would be possible. If vegetation cover decreased as a result of the presence of the repository, the amount of rainfall runoff and the amount of erosion and subsequent sedimentation could be higher. In rare cases of significant runoff, this could change the quality of surface water in the Yucca Mountain area.

S.5.1.6 Cultural Resources

Land disturbances associated with the Proposed Action could have direct impacts on cultural resources around Yucca Mountain. Archaeological investigations in the immediate vicinity of the proposed surface facilities during characterization studies and infrastructure construction combined with other cultural resource investigations in the area have identified 830 archaeological and historic sites in the analyzed land withdrawal area. Most of the archaeological sites are small scatters of stone artifacts. None of the sites has been listed on the *National Register of Historic Places,* but 150 are potentially eligible.

Repository development would disturb no more than about 4.5 square kilometers (1,100 acres) of previously undisturbed land at the site. Before repository development activities began, DOE would identify and evaluate archaeological or cultural resources sites for their importance and eligibility for inclusion on the *National Register of Historic Places*. DOE would avoid such sites if possible or, if avoidance were not possible, DOE would conduct a data recovery program in cooperation with tribal representatives and other appropriate officials and would document the findings. Artifacts and knowledge from the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Training, which is ongoing during site characterization activities, would continue to be provided to workers on the laws and regulations related to the protection of cultural resources.

Studies have described several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. DOE recognizes that Native Americans have concerns about protecting traditions and the spiritual integrity of the land in the Yucca Mountain region, and that these concerns extend to the propriety of the Proposed Action. The Consolidated Group of Tribes and

Organizations in the area surrounding the Yucca Mountain site value the cultural resources in the area, viewing them in a holistic manner. They believe that the water, animals, plants, air, geology, sacred sites, and artifacts are interrelated and dependent on each other for existence. Because of the general level of importance attributed to the land by these Native Americans, and because they regard the land as part of an equally important integrated cultural landscape, these Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment. The establishment of the land withdrawal boundary and construction of the repository would continue to restrict their free access to these areas. Figure S-21 shows traditional boundaries and locations of tribes in the region.

S.5.1.7 Socioeconomics

Southern Nevada has been one of the fastest-growing areas in the country, with its economy being driven by the growth of the hotel and gaming industry. Most of the Yucca Mountain Project and Nevada Test Site onsite employees live in Clark (93 percent of employees) and Nye (4 percent) Counties. Between 1990 and 2000, the population in the region of influence (Clark, Lincoln, and Nye Counties), led by Clark County, grew by 88 percent, compared to 66.3-percent population growth in Nevada and 13.1-percent population growth in the United States as a whole. Clark County reached a population of about 1.4 million in 2000 and added an average of more than 38,000 new jobs a year during the 1990s. Similarly, Nye County experienced an 83-percent growth rate for the decade, while Lincoln County's population increased by about 10 percent between 1990 and 2000. Although new jobs have been added to the region's economy each month, some potential employees lack necessary job skills. As a result, Clark County has maintained an unemployment rate that remains near State and national averages. In 2000, Nye and Lincoln Counties had unemployment rates above the State and national averages. In addition, the residential housing market is strong and steady; steady employment and population growth are spurring the demand for housing. Public services such as education, health care, law enforcement, and fire protection are adequate. However, these services likely will require expansion if the general growth in the economy and population continues.

The DOE evaluation of impacts to the socioeconomic environment in communities in the vicinity of the proposed repository considered changes to employment, population, economic measures, housing, and public services. For all five socioeconomic parameters evaluated, the impacts would be very small, less than 1 percent of the baselines for the region. For example, the largest change in population would range from less than 1 percent in Clark County and Nye County, to as high as 2.4 percent in Lincoln County (assuming the selection of a rail or heavy-haul transportation route in Lincoln County).

The lower-temperature repository operating mode with surface aging would have the highest potential socioeconomic impact due to the longer operation period. This scenario would result in a maximum of 0.3-percent increase in direct and indirect employment in the peak construction year (2006). Population increases caused by the increased employment opportunities would peak in 2030 at about 5,700, or less than 0.25 percent of the baseline for that year.

In light of public comments received on the Draft EIS concerning perceived risk and stigmatization, DOE reexamined relevant studies and literature to determine whether the state of the science in predicting future behavior based on perceptions had advanced sufficiently to allow DOE to quantify the impacts of public risk perception on economic development or property values in potentially affected communities. The following conclusions were reached from evaluation of these literature reviews plus scientific and social studies carried out in the past few years:

- While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable quantitative methods whereby such impacts could be predicted with any degree of certainty.

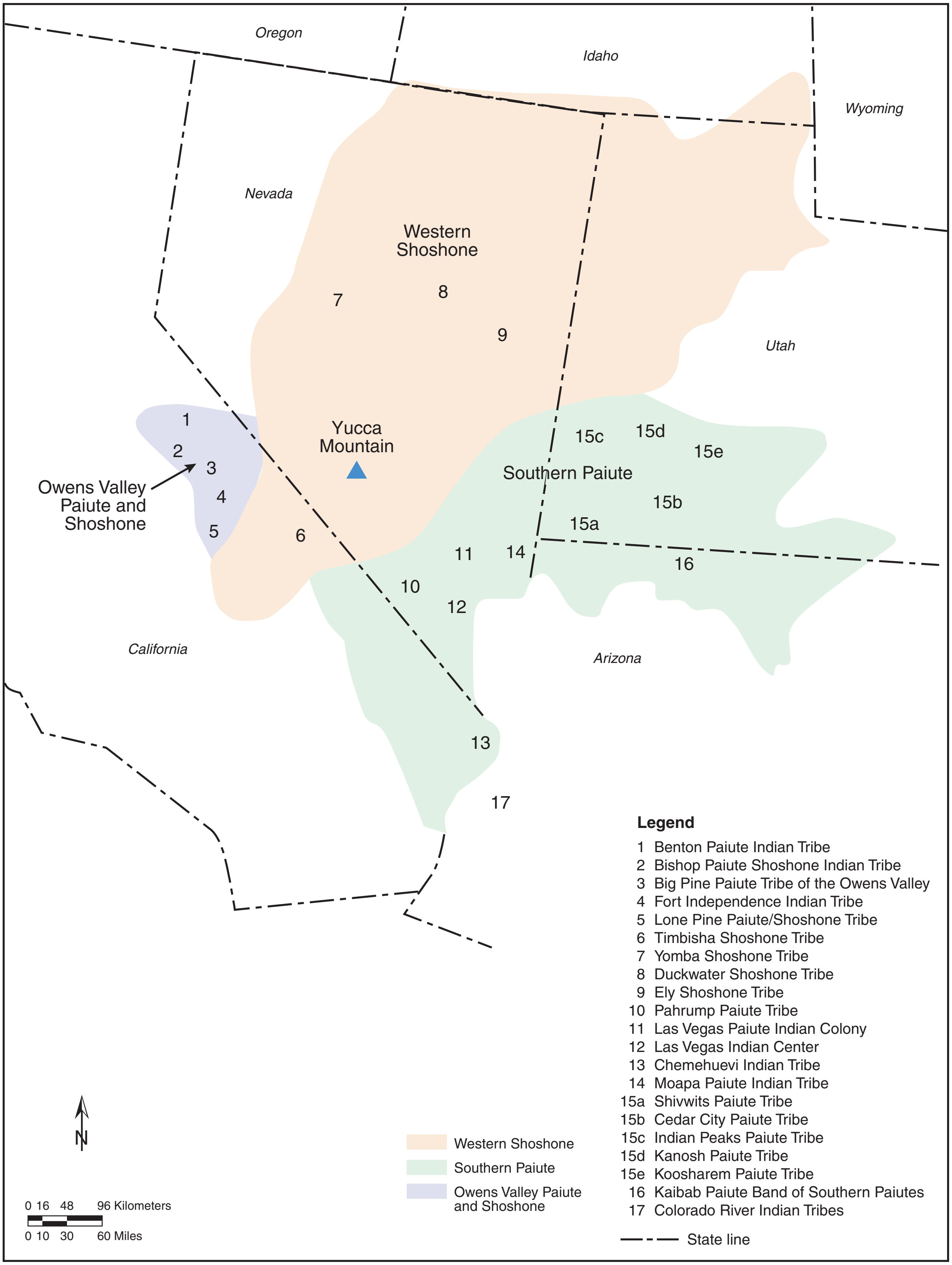

Figure S-21. Traditional boundaries and locations of tribes in the Yucca Mountain region.

- Much of the uncertainty is irreducible, and
- Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

S.5.1.8 Occupational and Public Health and Safety

The analysis of occupational and public health and safety considered short-term (prior to closure) health impacts from routine operations (1) to workers from hazards that are common to similar industrial settings and excavation operations, such as falling or tripping (referred to as industrial hazards), (2) to workers and the public from naturally occurring nonradiological materials in the rock under Yucca Mountain, (3) to workers as a result of radiation exposure during their work activities, and (4) to the public from airborne releases of radionuclides (estimated doses are described in Section S.4.1.2). The analysis separately considered involved workers (those who would participate in a particular activity) and noninvolved workers (those who would be on the site but would not participate directly in the activity in question).

Impacts to Workers from Industrial Hazards. Workers would be subject to industrial hazards during all phases of the Proposed Action. Examples of the types of industrial hazards that could present themselves include tripping, being cut on equipment or material, dropping heavy objects, and catching clothing in moving machine parts. Most impacts would be the result of fuel handling in the Waste Handling Building during the operations period. The next biggest component of industrial hazards would be the result of the subsurface excavation.

The estimated number of workplace fatalities from industrial hazards over the project life would range from 2.0 for the higher-temperature repository operating mode to between 2.2 and 3.3 for the lower-temperature operating mode.

Nonradiological Impacts to Workers and the Public. DOE would use engineering controls during subsurface work to control exposures of subsurface workers to dust that might contain cristobalite, a form of crystalline silica. If engineering controls could not keep dust concentrations below established limits, administrative controls such as respiratory protection would be used until engineered controls could reduce concentrations. Similar controls would be applied for surface workers if necessary. DOE expects that exposure of subsurface and surface workers to cristobalite would be well below applicable regulatory limits and that potential impacts to these workers would be low. Cristobalite concentrations at the site boundary would be small and unlikely to pose impacts to the public.

HEALTH AND SAFETY IMPACTS (AFFECTED INDIVIDUALS)

Workers
- Industrial hazards
  - Involved workers
  - Noninvolved workers
- Nonradiological impacts
  - Involved workers
  - Noninvolved workers
- Radiological impacts
  - Involved workers
  - Noninvolved workers

Public
- Nonradiological impacts
  - Maximally exposed individual
  - Population
- Radiological impacts
  - Maximally exposed individual
  - Population

Radiological Impacts to Workers. Radiological impacts to workers are reported both in terms of the increase in likelihood of a latent cancer fatality for an individual, and the increase in the total number of latent cancer fatalities for the total worker population. The probability of the maximally exposed worker incurring a latent cancer fatality from repository-related radiation exposure would range from about 0.0072 to 0.012 (7 to 12 chances in 1,000) for a 50-year working lifetime. The total estimated number of

LATENT CANCER FATALITIES

As used in this EIS, a latent cancer fatality is a death resulting from cancer that has been caused by exposure to ionizing radiation. There is typically a latent period between the time of radiation exposure and the time the cancer cells become active. Exposure to radiation that results in a 1-rem (1,000-millirem) lifetime dose causes an estimated 0.0005 chance of incurring a fatal cancer.

In a population of 10,000 people, national statistics indicate that about 2,224 people would die from cancer of one form or another. Using information developed by the International Commission on Radiological Protection, if all 10,000 people received a dose of 200 millirem during their lifetimes (in addition to the normal background radiation dose), an estimated 1 additional cancer fatality would occur in that population. However, we would not be able to tell which of the 2,225 fatal cancers was caused by radiation and, possibly, the additional radiation would cause no fatal cancers.

Sometimes, calculations of the number of latent cancer fatalities associated with radiation exposure do not yield whole numbers, and, especially in environmental applications, may yield numbers less than 1.0. For example, if each individual in a population of 100,000 received a total dose of 0.001 rem, the collective dose would be 100 person-rem and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons × 0.001 rem × 0.0005 latent cancer fatality per person-rem). How should one interpret a nonintegral number of latent cancer fatalities, such as 0.05? The answer is to interpret the result as a statistical estimate. That is, 0.05 is the *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people. For most groups, no one would incur a latent cancer fatality from the 0.001 rem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The *average* number of deaths over all of the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 is 1/4, or 0.25). The most likely outcome for any single group is 0 latent cancer fatalities.

latent cancer fatalities that could occur in the repository workforce from the radiation dose received over the entire project would be about 4.0 for the higher-temperature repository operating mode. For the lower-temperature operating mode, the number of latent cancer fatalities would range from 4.4 to 6.8 for the project duration, depending on the length of time before closure.

About 70 percent of the radiological impacts to workers for the Proposed Action would occur during the operations period. The principal contributor to these operations impacts would be surface facility operations, which would involve receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for emplacement. The second largest contributor to worker impacts would be subsurface monitoring, which would increase proportionately with the length of time monitoring would be carried out.

Preclosure Radiological Impacts to the Public. Short-term radiological health impacts to the public for Yucca Mountain construction, operation and monitoring, and closure would be small. (Impacts from transportation are discussed in Section S.4.2.) More than 99.9 percent of the potential health impact would be from naturally occurring radon-222 and its decay products released in exhaust ventilation air. The highest annual dose would range from 0.73 to 1.3 millirem, less than 1 percent of the annual 200-millirem dose that members of the public in Amargosa Valley would receive from ambient levels of naturally occurring radon-222 and its decay products.

The maximally exposed individual would have an increase in the probability of incurring a latent cancer fatality ranging from about 0.000016 to 0.000031 (from 16 to 31 chances in 1,000,000) from exposure to radionuclides released from repository facilities over a 70-year lifetime. The total estimated number of latent cancer fatalities in the potentially exposed population would range from 0.46 for the higher-temperature operating mode to 0.97 to 2.0 for the lower-temperature repository operating mode.

For the sake of comparison, statistics published by the Centers for Disease Control indicate that, during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause. Assuming this mortality rate would remain unchanged for the estimated population in 2035 of about 76,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 18,000 members of this population would be likely to die from cancer-related causes unrelated to the Proposed Action. During the time the project was active (100 to 324 years), the number of cancer deaths unrelated to the project would range from 30,000 to 89,000 in the general population. Estimated project-related impacts (0.46 to 2.0) would be a very small increase (0.007 percent or less) over this baseline.

Long-Term Radiological Health Impacts. DOE considered potential long-term human health impacts for 10,000 years from the start of emplacement. The analysis estimated potential human health impacts due to processes and events such as corrosion of waste packages, dissolution of waste forms, seismic events, and changing climate. In addition, it considered the effects of such disturbances as exploratory drilling or volcanic events.

The heat generated by spent nuclear fuel and high-level radioactive waste could affect both the short-term (before repository closure) and the long-term performance of the repository (that is, the ability of the engineered and natural barrier system to isolate the emplaced waste from the accessible environment for long periods). The temperature of the repository after emplacement of spent nuclear fuel and high-level radioactive waste could have a direct effect on the corrosion rate and integrity of the waste packages. Further, the repository temperature could affect the geochemistry, hydrology, and mechanical stability of the emplacement drifts, which in turn could influence groundwater flow and the transport of radionuclides from the engineered and natural barrier systems to the environment.

UNCERTAINTY IN LONG-TERM PERFORMANCE

Uncertainty is associated with estimates of long-term repository performance. The uncertainty regarding a repository's long-term performance was handled in two ways. First, where the uncertainty was considered very important to the outcome, conservative assumptions were used that tended to overstate the risks that would be obtained by a more realistic model. Second, ranges of data were used in a probabilistic sampling routine to produce ranges of results that reflected the effect of the range of inputs.

For the range of repository operating modes, radioactive materials that entered the groundwater would produce the primary impacts from the repository to human health in the far future. Figure S-22 shows the potential movement of contaminants from the repository to the accessible environment. The analysis estimated human health impacts from the groundwater pathway at three locations in the Yucca Mountain region: water wells approximately 18 and 30 kilometers (11 and 19 miles) from the repository and the nearest surface-water discharge point, which is about 60 kilometers (37 miles) away. The estimated health impact is expressed as the probability of a resulting latent cancer fatality from lifetime use of the contaminated water.

Under the entire range of repository operating modes, less than 1 latent cancer fatality would be likely over the 10,000-year analysis period. The analysis indicated that the higher-temperature operating mode would have a low, but nonetheless higher, annual dose [0.00002 millirem at 18 kilometers (11 miles)] and correspondingly greater health effects on the reasonably maximally exposed individual (lifetime probability of a latent fatal cancer of 6×10^{-10}) than the range of lower-temperature modes. In addition, concentrations of chemically toxic materials were found to be lower than identified Maximum

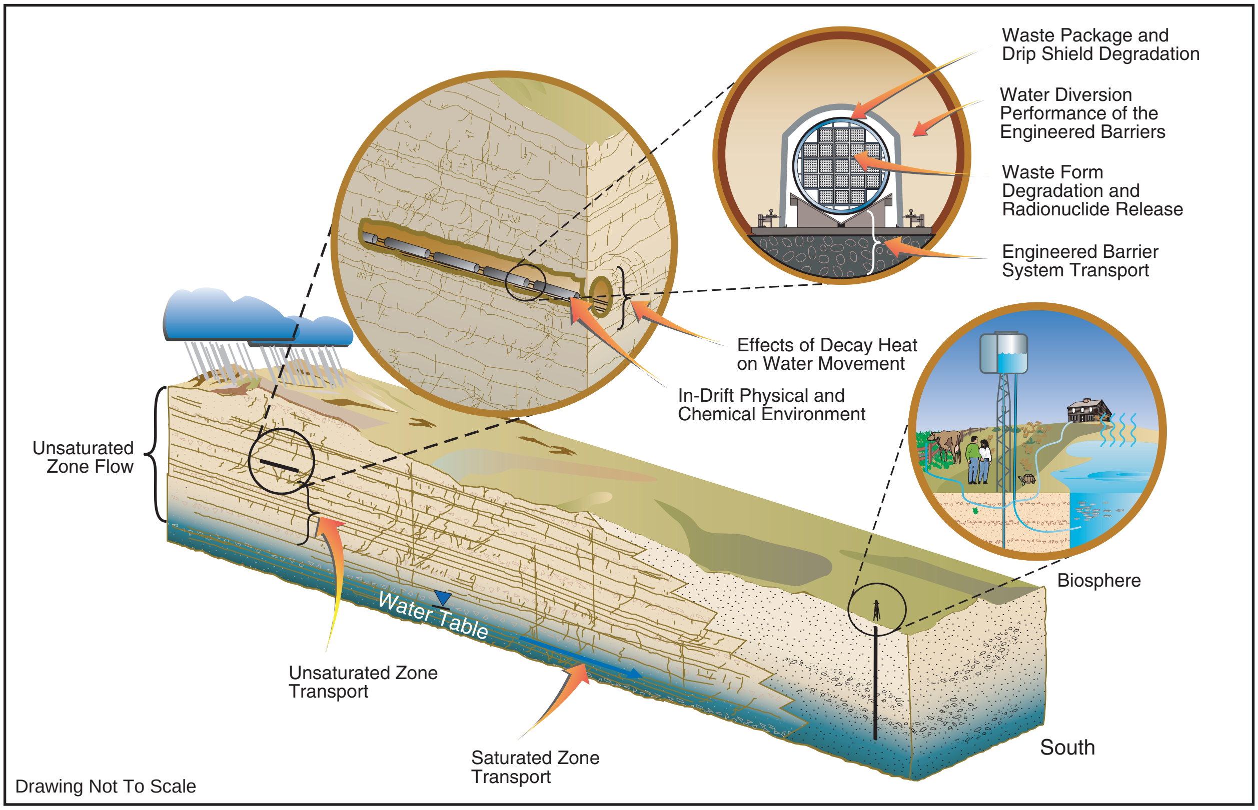

Figure S-22. Schematic illustration of the processes modeled for Total System Performance Assessment.

Contaminant Level Goals. Where no levels or goals have been established were found to be very low. Therefore, DOE does not anticipate detrimental impacts to water quality or human health from toxic materials.

In addition, DOE estimated the annual dose for 1 million years after repository closure. For the higher-temperature repository operating mode, the peak annual dose would be 150 millirem to a reasonably maximally exposed individual approximately 18 kilometers (11 miles) from the repository, occurring 480,000 years after closure (120 millirem under the lower-temperature operating mode). Variations in the peak annual dose to a reasonably maximally exposed individual among the range of operating modes would be caused by earlier waste package failures under the higher-temperature operating mode, placement of waste packages in different areas of the repository, and different amounts of water infiltrating through the different repository areas.

The analysis of a drilling intrusion event occurring at 30,000 years indicated a peak of the mean annual dose to the reasonably maximally exposed individual approximately 18 kilometers (11 miles) downstream of the repository would be 0.002 millirem, occurring a short time after 100,000 years. The analysis of an igneous activity scenario, including a volcanic eruption event and igneous intrusion event indicated a peak of the mean annual dose to the reasonably maximally exposed individual approximately 18 kilometers downstream of the repository would be 0.1 millirem.

Congress, in the Energy Policy Act of 1992, directed the Environmental Protection Agency to develop public health and safety standards for the protection of the public from releases of radioactive materials stored or disposed of in a repository at the Yucca Mountain site. Congress also directed the Nuclear Regulatory Commission to publish criteria for licensing a repository that would be consistent with the radiation protection standards established by the Environmental Protection Agency. In part, the

Environmental Protection Agency standards (40 CFR Part 197) and Nuclear Regulatory Commission criteria (10 CFR Part 63) prescribe radiation exposure limits that the repository, based on a performance assessment, cannot exceed during a 10,000-year period after closure.

In the EIS, DOE has evaluated the environmental impacts of a natural and engineered barrier system designed to isolate radioactive materials from the environment for thousands of years. As a result of this evaluation, DOE would not expect the repository to result in impacts to public health beyond those that could result from the prescribed radiation exposure and activity concentration limits during the 10,000-year period after closure.

S.5.1.9 Accident Scenarios

> **ACCIDENT**
>
> An unplanned event or sequence of events that results in undesirable consequences.

The evaluation of accident scenarios associated with the Proposed Action included the potential for radiological accidents and accidents involving exposure to hazardous and toxic substances before repository closure. The potentially affected individuals considered include (1) the maximally exposed individual, a hypothetical member of the public at the point on the site boundary who would receive the largest dose, (2) the involved worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the noninvolved worker near the accident but not involved in handling the material, and (4) members of the public living within about 80 kilometers (50 miles) of the repository. The accident scenario analysis examined consequences under both median (50th-percentile) meteorological conditions and highly unfavorable meteorological conditions (95th-percentile, or those that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts.

Initiators of radiological accident scenarios could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material. They include human-caused events such as aircraft crashes, external fires and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. In addition, the analysis used bounding (maximum reasonably foreseeable) accident scenarios to represent the impacts from groups of similar accidents. Finally, it evaluated the consequences of the postulated accident scenarios by estimating the potential radiation dose and radiological impacts.

The radionuclide source term for various accident scenarios could involve several different types of radioactive materials. These would include commercial spent nuclear fuel from both boiling- and pressurized-water commercial reactors, DOE spent nuclear fuel, high-level radioactive waste incorporated in a glass matrix, and weapons-grade plutonium either immobilized in a high-level radioactive waste glass matrix or as mixed-oxide fuel. In addition, the analysis examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

In a change from the analysis in the Draft EIS, DOE used a "representative fuel assembly" for all accident analyses for the repository. The Draft EIS used average fuel assemblies that were aged approximately 26 years out of the reactor. Based on a relative hazard index, the representative fuel assemblies analyzed in the Final EIS are only about 14 years out of the reactor and have a higher burnup, meaning they contain a higher concentration of radionuclides than those used in the Draft EIS analyses, and therefore result in more conservative impact estimates than those presented in the Draft EIS.

Main Index

After a screening to determine the internal and external initiators that would be applicable to the repository and that are considered reasonably foreseeable, 10 accident scenarios were analyzed in detail. These accidents include both low-probability/high-consequence events and high-probability/low-consequence events. These scenarios bound the risks of credible accidents at the repository. They include accidents in the Cask Handling Area, the Canister Transfer System, the Assembly Transfer System, the Disposal Container Handling Area, the Surface Aging Facility, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter. The maximum reasonably foreseeable accident (a credible accident scenario with the highest foreseeable consequences) was determined to be a beyond-design-basis seismic event. For this accident, using unfavorable weather conditions, the impacts to the maximally exposed offsite individual would be 38 millirem and would result in an estimated 0.011 additional latent cancer fatality for the population within 80 kilometers (50 miles) of the repository.

Impacts to the noninvolved worker from the reasonably foreseeable accidents would result in a maximum dose of 25 rem during the beyond-design-basis seismic event. This maximum dose would correspond to a 1-percent chance of incurring a latent cancer fatality. Severe accidents would be likely to result in the deaths of some involved workers.

DOE evaluated the likelihood of an accidental crash of aircraft (military and commercial) into the surface aging facility. The analysis determined that the aircraft would not penetrate the storage modules and a release of radioactive materials would not occur.

In response to public comments and to provide further information about accident risks, DOE analyzed an accident scenario in which a large commercial jet aircraft would crash into the repository facilities. The probability of this accident is less likely than the threshold considered reasonably foreseeable (1 in 10 million). However, if the accident occurred, the estimated consequences would include a dose of 4.5 rem to the maximally exposed offsite individual and a corresponding likelihood of 0.0023 that this individual would incur a fatal cancer. The consequences to the population for this event would be 78 person-rem and an estimated 0.039 latent cancer fatality. In addition, passengers on board the aircraft and any workers in the vicinity of the crash could perish.

A release of hazardous or toxic (nonradiological) materials during accidents involving spent nuclear fuel or high-level radioactive waste at the repository, however, would be very unlikely. The repository would not accept hazardous waste, although some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. Because such waste would be contained in a glass or ceramic matrix, exposure of workers or members of the public from any accident would be highly unlikely. In any event, because of the large quantity of radioactive material, radiological considerations would outweigh nonradiological concerns under most accident conditions.

S.5.1.10 Noise and Vibration

Background noise at Yucca Mountain is caused by natural phenomena such as rain and wind and noise from people, including vehicles from site characterization activities and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain site were consistent with noise levels associated with industrial operations (sound levels from 44 to 72 decibels). Background levels of ground vibration at Yucca Mountain are also low. Other than site characterization activities, there is a lack of sources of ground vibration impacts (pile-driving, heavy earthmoving equipment, blasting).

Repository activities during construction, operation, and closure that could generate elevated noise levels would include use of heavy equipment, ventilation fans, diesel generators, transformers, and a concrete batch plant.

Workers at the repository site could be exposed to elevated levels of noise. However, worker exposures to elevated noise levels during all repository phases would be controlled by the use of protective equipment, so impacts from noise would be unlikely.

The distance from the Yucca Mountain site to the nearest housing is about 22 kilometers (14 miles). Based on an estimated maximum noise level from repository operations, DOE calculated that noise from the repository would be at the lower limit of human hearing at 6 kilometers (3.7 miles). For this reason, DOE expects that noise impacts to the public from repository construction and operations would be small.

S.5.1.11 Aesthetics

Yucca Mountain has visual characteristics fairly common to the region, and the visibility of the site from publicly accessible locations is low or nonexistent. The intervening Striped Hills and the low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near the Town of Amargosa Valley, approximately 22 kilometers (14 miles) away. There is no public access to the north or east of the repository site to enable viewing of the facilities. The only structures that could potentially be visible from the west that exceed the elevation of the southern ridge of Yucca Mountain [1,500 meters (4,900 feet)] would be the exhaust ventilation stacks and support structures that would be constructed along the crest of the mountain.

DOE would provide lighting for operation areas at the repository that could be visible from public access points. However, there would not be significant visual impacts due to repository lighting to users of Death Valley National Park. The Towns of Amargosa Valley, Beatty, and Pahrump, located between the park and the proposed repository, would probably cause greater impacts to the nightly viewshed than operational lighting at the repository site. The visual impact of the lighting from Las Vegas would also be more significant in the region than that of the repository. The use of shielded or directional lighting at the repository would limit the amount of light that could be seen from outside the repository area. Closure activities, such as dismantling facilities and reclaiming the site, would restore the visual quality of the landscape, as viewed from the site itself.

S.5.1.12 Utilities, Energy, Materials, and Site Services

The scope of the analysis included electric power use, fossil-fuel consumption, consumption of construction materials, and onsite services such as emergency medical support, fire protection, and security and law enforcement. Overall, DOE does not expect large impacts to residential water, energy, materials, and emergency services from the Proposed Action.

Electricity. The repository demand for electricity would be well within the expected regional capacity for power generation. The current electric power supply line has a capacity of 10 megawatts. During the early stages of repository operations, when emplacement activities would be occurring while new drifts were being developed, the peak electric power demand would be between 40 and 54 megawatts, depending on the operating mode. Therefore, DOE would need to enhance the electric power delivery system to the Yucca Mountain site. The solar power generating facility, which could produce as much as 3 megawatts of power, would be a dual-purpose facility, serving as a demonstration of photovoltaic power generation and augmenting the overall repository electric power supply (as much as 7 percent).

Fossil Fuel. Fossil fuel would include diesel fuel, gasoline, and fuel oil. Yearly repository use during construction would be less than 1 percent of the current use in Clark, Lincoln, and Nye Counties, and should result in only small impacts to fossil-fuel supplies.

Fossil-fuel use during the operation and monitoring phase would be highest during emplacement and development operations and would decrease substantially during monitoring and maintenance activities.

The highest annual use would be less than 5 percent of the 1996 use in Clark, Lincoln, and Nye Counties. Thus, the projected use of liquid fossil fuels should be within the available regional capacity and should result in only small impacts to fossil-fuel supplies. Hydraulic oils and lubricants and nonfuel hydrocarbons would be used to support equipment operation. These materials would be recycled and reused.

Construction Materials. The primary materials needed to build the repository would be concrete, steel, and copper. Concrete, which consists of cement and aggregate, would be used for tunnel liners in main drifts and ventilation shafts and the construction of surface facilities. DOE would use regionally available aggregate for concrete, and would purchase cement regionally. The lower-temperature repository operating mode would require the largest amount of concrete (up to 1.4 million cubic meters or 1.8 million cubic yards), which would be less than about 3 percent of the amount used in Nevada in 1998. Because steel and copper have worldwide markets, DOE expects little or no impact from an increased demand for steel and copper in the region.

Site Services. An emergency response system would be established to respond to accidents at the repository site. The capabilities would include emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground. The onsite service capabilities would be able to respond to most events, including underground events, without outside support. Therefore, a large impact on the emergency services of surrounding communities or counties would be unlikely.

S.5.1.13 Waste Management

The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, and radioactive wastes that repository-related activities would generate. DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater, or could use a landfill at the Nevada Test Site. DOE would use less than 4 percent of the existing available offsite capacity for low-level radioactive waste disposal at the Nevada Test Site and a smaller fraction of the available hazardous waste disposal capacity.

S.5.1.14 Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs Federal agencies to work to achieve "environmental justice" by identifying and addressing the potential for their activities to cause disproportionately high and adverse impacts to minority and low-income populations. As part of this process, DOE has identified the minority and low-income communities in Clark, Lincoln, and Nye Counties, using U.S. Bureau of the Census population designations to determine areas with high concentrations of minority or low-income populations.

DOE considered the potential for disproportionately high and adverse impacts to minority and low-income populations under both normal and accident conditions using the identified potential impacts to the general population and an assessment of potential unique pathways, sensitivities, or cultural practices that could

POPULATIONS

Minority: individuals who are American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic. For this EIS, a minority community is one in which the percent of the population of a racial or ethnic minority is 10 percentage points higher than the percent found in the population as a whole.

Low income: individuals with an income below the poverty level defined by the U.S. Bureau of the Census. A low-income population is one in which 20 percent or more of the persons in the population live in poverty.

result in high and adverse impacts on minority and low-income populations. The EIS analyses determined that the impacts that could occur to public health and safety would be small for the population as a whole for all phases of the Proposed Action, and that no subsections of the population, including minority or low-income populations, would receive disproportionately high and adverse impacts. The Department recognizes, however, that Native American tribes in the region consider the intrusive nature of the repository and continuation of restrictions on access to lands where the repository would be located to have an adverse impact on all elements of the natural and physical environment and to their way of living within that environment.

S.5.1.15 Sabotage

In the aftermath of the tragic events of September 11, DOE is continuing to assess measures that it could take to minimize the risk or potential consequences of radiological sabotage or terrorist attacks against our Nation's proposed monitored geologic repository.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level radioactive waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (prior to closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by Federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

Current Nuclear Regulatory Commission regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides "high assurance that activities involving spent nuclear fuel and high-level waste do not constitute an unreasonable risk to public health and safety." The regulations require that spent nuclear fuel and high-level radioactive waste be stored in a protected area such that:

- Access to the material requires passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, be continually monitored, and be protected by an active alarm system.
- Adequate illumination must be provided for observation and threat assessment.
- The area must be monitored by random patrol.
- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

A trained, equipped, and qualified security force is required to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat. Liaison with a response force is required to permit timely response to unauthorized entry or activities. In addition, the Nuclear Regulatory Commission requires (10 CFR Part 63, by reference to 10 CFR Part 72) that comprehensive receipt, periodic inventory, and disposal records be kept for spent nuclear fuel and high-level radioactive waste in storage. A duplicate set of these records must be kept at a separate location.

DOE believes that the safeguards applied to the proposed repository should involve a dynamic process of enhancement to meet threats, which could change over time. Repository planning activities would continue to identify safeguards and security measures that would further protect fixed facilities from terrorist attack and other forms of sabotage. Additional measures that DOE could adopt include:

- Facilities with thicker reinforced walls and roofs designed to mitigate the potential consequences of the impact of airborne objects
- Underground or surface bermed structures to lessen the severity of damage in cases of aircraft crashes
- Additional doors, airlocks, and other features to delay unauthorized intrusion
- Additional site perimeter barriers to provide enhanced physical protection of site facilities
- Active denial systems to disable any adversaries, thereby preventing access to the facility

Although it is not possible to predict if sabotage events would occur, and the nature of such events if they did occur, DOE examined various accident scenarios that approximate the types of consequences that could occur. These accidents and their consequences are discussed in Section S.5.1.9.

S.5.2 TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would take place at 72 commercial and 5 DOE sites. Legal-weight trucks and trains would travel on the Nation's highways and railroads. Barges and heavy-haul trucks could be used for the short-distance transport of spent nuclear fuel from some commercial sites to nearby railroads. Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would travel to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. Legal-weight truck shipments would use existing highways in accordance with U.S. Department of Transportation regulations. Figures S-13 and S-14 show the alternatives for rail corridors and intermodal transfer station locations and associated heavy-haul truck routes, respectively, in the State of Nevada.

DOE analyzed the impacts of transporting these materials to the repository under the mostly legal-weight truck and mostly rail scenarios. Under the mostly legal-weight truck scenario, most of the spent nuclear fuel and high-level radioactive waste would be shipped to Nevada by legal-weight truck, while naval fuel would be shipped by rail. Under the mostly rail scenario, commercial spent nuclear fuel from most sites and DOE and naval spent nuclear fuel and high-level radioactive waste would arrive in Nevada by rail. However, commercial fuel from a few commercial sites would initially be shipped by legal-weight truck because those sites do not currently have the capability to load a rail cask.

At present, there is no rail access to the Yucca Mountain site. If material was shipped by rail, a branch line that connected an existing main line to the Yucca Mountain site would have to be built or the material would have to be transferred to heavy-haul trucks at an intermodal transfer station and transported over existing highways that might need upgrading. DOE examined the environmental impacts that would be associated with a new branch rail line (five alternative rail corridors) and with an intermodal transfer station (three alternative locations) and heavy-haul truck routes (five alternative routes).

S.5.2.1 National Transportation Impacts

National transportation includes the impacts of transporting spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site. Much of the difference in the impacts between the mostly legal-weight truck and mostly rail scenarios would result from the differing number of shipments over the 24-year transportation period and differences in the characteristics of the truck and rail modes of transport. The mostly legal-weight truck scenario would involve about

53,000 shipments (2,200 annually), and the mostly rail scenario would involve approximately 10,700 shipments (450 annually). Primarily because of the larger number of shipments, the mostly legal-weight truck scenario would have greater incident-free radiological impacts (latent cancer fatalities), even though each individual truck shipment would carry less radioactive material than a rail shipment.

The EIS analysis considered potential accidents based on the 19 truck and 21 rail accident cases presented in NUREG-6672, *Reexamination of Spent Fuel Shipment Risk Estimates.* In addition, the analysis estimated impacts of postulated releases from accidents in three population zones—urban, suburban, and rural—under a set of meteorological (weather) conditions that represent the national average meteorology. The analysis used state-specific accident data, the lengths of routes in the population zones in states through which the shipments would pass, and the number of shipments that would use the routes to determine accident probabilities.

ESTIMATED NATIONAL TRANSPORTATION IMPACTS
(for 24 years of operation)

Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Incident-free latent cancer fatalities		
Involved worker	12	3
Public[a]	3	1
Latent cancer fatalities from accidents		
Public	0.00023	0.00045
Traffic fatalities[b]	5	3
Latent cancer fatalities from maximum reasonably foreseeable accident	0.55	5
Frequency of occurrence per year	2.3×10^{-7}	2.8×10^{-7}

a. These latent cancer fatalities would result from very low doses to a very large population.
b. Does not include 10 to 17 fatalities that could occur from repository workers commuting and transporting construction materials to the repository.

In addition to the risk due to accidents involving a release of radioactive material, the analysis examined the impacts of loss-of-shielding accidents. The loss-of-shielding scenarios range from an accident with no loss of shielding to a low-probability severe accident involving both a loss of shielding (and any increased direct exposure) and a release of some of the contents of the cask.

The EIS analysis also estimated impacts from an unlikely but severe accident called a *maximum reasonably foreseeable accident* to provide perspective about the consequences for a population that might live nearby. For maximum reasonably foreseeable accidents, the consequences were estimated for each of the accidents and for both truck and rail casks from the spectrum of accidents presented in NUREG-6672. For each accident, the possible combinations of weather conditions, population zones, and transportation modes were considered. The accidents were then ranked according to those that would have a likelihood greater than 1 in 10 million per year and that would have the greatest consequences.

Real life transportation accidents involve collisions of many kinds, such as with other vehicles and along-the-route obstacles, involvement in fires and explosions, inundation, and burial. These accidents are caused, in turn, by a variety of initiating events including human error, mechanical failure, and natural causes such as earthquakes. Accidents occur in many different kinds of places including mountain passes and urban areas, rural freeways in open landscapes, and rail switching yards.

Thus, there are as many different kinds of unique initiating events and accident conditions as there are accidents. Analyzing each accident that could occur would not be practical. However, it is practical to analyze a limited number of accidents, each of which represents a grouping of initiating events and conditions having similar characteristics. For example, the EIS analyzes the impacts of a collection of collision accidents in which a cask would be exposed to impact velocities in the range of 97 to 145 kilometers (60 to 90 miles) per hour. The EIS also analyzes a maximum reasonably foreseeable accident in which a collision would not occur but where the temperature of a rail cask containing spent nuclear fuel would rise to between 750°C and 1,000°C (between 1,400°F and 1,800°F). The conditions of the maximum reasonably foreseeable accident analyzed in the EIS envelop conditions reported for the Baltimore Tunnel fire (a train derailment and fire that occurred in July 2001 in a tunnel in Baltimore, Maryland). Temperatures in that fire were reported to be as high as 820°C (1,500°F), and the fire was reported to have burned for up to 5 days.

DOE also evaluated the potential consequences of an accidental crash of a large jet aircraft into a truck cask or rail cask. The analysis determined that penetration of the cask would not occur; however, potential seal failure could result in releases of radiological materials. The consequences associated with this event would be less than 1 latent cancer fatality in an urban population.

The consequences of the maximum reasonably foreseeable transportation accident (an accident with the highest consequence for human health that can be reasonably foreseen) would be higher under the mostly rail scenario (5 latent cancer fatalities) than under the mostly legal-weight truck scenario (1 latent cancer fatality) principally because the amount of material in a rail shipment would be larger than that in a legal-weight truck shipment.

The Nuclear Regulatory Commission has developed a set of rules specifically aimed at protecting the public from harm that could result from sabotage of spent nuclear fuel casks. Known as physical protection and safeguards regulations (10 CFR 73.37), these security rules are distinguished from other regulations that deal with issues of safety affecting the environment and public health. The objectives of the physical protection and safeguard regulations are to:

- Minimize the possibility of sabotage
- Facilitate recovery of spent nuclear fuel shipments that could come under control of unauthorized persons

The cask safety features that provide containment, shielding and thermal protection also provide protection against sabotage. The casks would be massive. The spent nuclear fuel in a cask would typically be only about 10 percent of the gross weight; the remaining 90 percent would be shielding and structure.

It is not possible to predict whether sabotage events would occur and, if they did, the nature of such events. Nevertheless, DOE examined various accidents, including an aircraft crash into a transportation cask. The consequences of both the maximum reasonably foreseeable accident and the aircraft crash are presented above for the mostly truck and mostly rail transportation scenarios and can provide an approximation of the type of consequences that could occur from a sabotage event. In addition, DOE analyzed the potential consequences of a saboteur using a device on a truck or rail cask. The results of this analysis indicate that the risk of the maximally exposed individual incurring a fatal cancer would increase from approximately 23 percent (the current risk of incurring a fatal cancer from all other causes) to about 29 percent. The same event could cause 48 latent cancer fatalities in an assumed population of a large urban area.

Because of the terrorist attack of September 11, 2001, the Department and other agencies are reexamining the protections built into their physical security and safeguards systems for transportation shipments. As dictated by results of this reexamination, DOE would modify its methods and systems as appropriate.

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S.5.2.2 Nevada Transportation Impacts

The analysis of national transportation includes the analysis of transportation from 77 generation sites to Yucca Mountain. This includes transportation in the State of Nevada. To present a more focused description of impacts in Nevada, the EIS discusses Nevada transportation separately as well. Spent nuclear fuel and high-level radioactive waste shipped to the repository by legal-weight truck would continue in the same vehicles to the Yucca Mountain site. Material that traveled by rail would either continue to the repository on a newly constructed branch rail line or transfer to heavy-haul trucks at an intermodal transfer station that DOE would build in Nevada for shipment on existing highways that could require upgrades. Selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul truck routes, would require additional field surveys; environmental and engineering analysis; State, local, and Native American government consultation, and National Environmental Policy Act reviews.

Rail Corridor Implementing Alternatives. DOE assessed five rail implementing alternatives—the Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified corridors (see Figure S-13). The assessment considered the impacts of constructing a branch rail line in one of the five 400-meter (0.25-mile)-wide corridors including variations of the corridors. Each corridor would connect the Yucca Mountain site with an existing mainline railroad in Nevada.

Intermodal Transfer Station and Heavy-Haul Truck Route Implementing Alternative. DOE assessed alternative intermodal transfer station locations at rail terminals near Caliente, Apex/Dry Lake, and Sloan/Jean (see Figure S-14). The intermodal transfer station would transfer casks containing spent nuclear fuel and high-level radioactive waste from railcars to heavy-haul trucks and empty casks from heavy-haul trucks to railcars. In addition, DOE assessed three alternative heavy-haul truck routes from a Caliente intermodal transfer station—Caliente, Caliente/Chalk Mountain, and Caliente/Las Vegas—and one route each from the Apex/Dry Lake and Sloan/Jean locations. This implementing alternative probably would include an average of 110 legal-weight truck shipments of commercial spent nuclear fuel each year from the six sites that do not currently have the capability to load rail casks.

Estimated impacts for any of the five alternative rail corridors or five heavy-haul truck routes over the 24 years of transport operations would include the following:

- The incident-free collective dose to members of the public would result in less than 1 latent cancer fatality.
- The cumulative radiological accident risk would be less than 0.0002 latent cancer fatality, taking into account both the probability of accident occurrence and the resulting consequences if an accident were to occur.
- The likelihood of the maximum reasonably foreseeable accident in an urbanized area nationally is about 2.3 to 2.8 chances in 10 million per year; if such an accident were to occur, from 1 to 5 latent cancer fatalities could result.
- From 1 to 5 fatalities would be likely to occur due to traffic accidents.
- The amount of land disturbed (for an intermodal transfer station and mid-route stops) would be small, generally less than 0.3 square kilometer (75 acres).

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RAIL CORRIDOR IMPACTS

Caliente

- 513 kilometers (319 miles) long, requiring about 10 hours to complete a one-way trip.
- Would disturb 18 square kilometers (4,500 acres) of land.
- 842 new jobs (direct and indirect) could be created during 46 months of construction.
- Estimated life-cycle cost is $880 million (2001 dollars).
- Other: One potential alignment would pass through Timbisha Shoshone Trust Lands.

Carlin

- 520 kilometers (323 miles) long, requiring about 9 hours to complete a one-way trip.
- Would disturb 19 square kilometers (4,900 acres) of land.
- 783 new jobs (direct and indirect) could be created during 46 months of construction.
- Estimated life-cycle cost is $821 million (2001 dollars).
- Other: One potential alignment would pass through Timbisha Shoshone Trust Lands.

Caliente-Chalk Mountain

- 345 kilometers (214 miles) long, requiring about 8 hours to complete a one-way trip.
- Would disturb 13 square kilometers (3,000 acres) of land.
- 647 new jobs (primary and secondary) could be created during 43 months of construction.
- Estimated life-cycle cost is $622 million (2001 dollars).
- Nonpreferred alternative: Strongly opposed by the U.S. Air Force because of the adverse effect on security and operations at Nellis Air Force Range.

Jean

- 181 kilometers (114 miles) long, requiring about 4 hours to complete a one-way trip.
- Would disturb 9 square kilometers (2,000 acres) of land.
- 526 new jobs (direct and indirect) could be created during 43 months of construction.
- Estimated life-cycle cost is $462 million (2001 dollars).
- Other: Could affect scenic quality lands and habitat for desert tortoise; would pass near the Las Vegas metropolitan area.

Valley Modified

- 159 kilometers (98 miles) long, requiring about 3 hours to complete a one-way trip.
- Would disturb 5 square kilometers (1,240 acres) of land.
- 245 new jobs (direct and indirect) could be created during 40 months of construction.
- Estimated life-cycle cost is $283 million (2001 dollars).
- Other: Could affect Desert National Wildlife Range on Nellis Air Force Range, would pass near Las Vegas Paiute Indian Reservation; would pass near the Las Vegas metropolitan area.

- Impacts to biological resources due to habitat disturbance and loss of individuals of affected species would be small. In particular, the activities associated with constructing a branch line, building an intermodal transfer station, or upgrading and maintaining a heavy-haul truck route to Yucca Mountain would be likely to adversely affect a few individual desert tortoises; these activities would not negatively affect regional populations of desert tortoises, jeopardize the continued existence of the species, or result in adverse modification of designated critical habitat.

- Based on an assessment, potential impacts from activities in floodplains and wetlands would be small.

HEAVY-HAUL TRUCK ROUTE IMPACTS

Caliente

- 533 kilometers (331 miles) long, requiring 2 days to complete a one-way trip.
- 856 new jobs (direct and indirect) could be created during 35 months of construction.
- Estimated life-cycle cost is $669 million (2001 dollars).
- Other: Could have visual impacts to Kershaw-Ryan State Park; would pass adjacent to Timbisha Shoshone Trust Lands.

Caliente/Chalk Mountain

- 282 kilometers (175 miles) long, requiring 2 days to complete a one-way trip.
- 751 new jobs (primary and secondary) could be created during 26 months of construction (levels of employment reflect assumption of $463-million estimate to complete the northern portion of the Las Vegas Beltway).
- Estimated life-cycle cost is $548 million (2001 dollars).
- Nonpreferred alternative: Strongly opposed by the U.S. Air Force because of the adverse effect on security and operations at the Nellis Air Force Range.
- Could have visual impacts to Kershaw-Ryan State Park.

Caliente/Las Vegas

- 377 kilometers (234 miles) long, requiring 2 days to complete a one-way trip.
- 1,979 new jobs (direct and indirect) could be created during 46 months of construction.
- Estimated life-cycle cost is $607 million (2001 dollars).
- Other: Could have visual impacts to Kershaw-Ryan State Park and would pass near the Las Vegas metropolitan area; would pass near the Moapa Indian Reservation and through the Las Vegas Paiute Indian Reservation.

Sloan/Jean

- 188 kilometers (118 miles) long, requiring one-half day to complete a one-way trip.
- 3,047 new jobs (direct and indirect) could be created during 48 months of construction (levels of employment reflect assumption of $790 million estimate to complete the Southern and Western portions of the Las Vegas Beltway).
- Estimated life-cycle cost is $444 million (2001 dollars).
- Other: Would pass near the Las Vegas metropolitan area; would pass through the Las Vegas Paiute Indian Reservation.

Apex/Dry Lake

- 183 kilometers (114 miles) long, requiring one-half day to complete a one-way trip.
- 1,882 new jobs (direct and indirect) could be created during 28 months of construction (levels of employment reflect assumption of $790-million estimate to complete the northern portion of the Las Vegas Beltway).
- Estimated life-cycle cost is $387 million (2001 dollars).
- Other: Would pass near the Las Vegas metropolitan area; could pass near the Moapa Indian Reservation and through the Las Vegas Paiute Indian Reservation.

- There could be visual impacts from the existence of the branch rail line, access road, and borrow pits in the landscape and the passage of trains to and from the repository along any rail corridor.

- There would be no effect on the general availability of gasoline, diesel fuel, steel, or concrete.

- There would be no disproportionately high and adverse impacts to minority and low-income populations. DOE considered impacts that would be associated with potential routes for rail and legal-weight and heavy-haul trucks that would pass through or near the Moapa and Las Vegas Paiute Indian Reservations and the newly established Timbisha Shoshone Trust Lands.

The factors that differ among the alternative transportation corridors and routes are length and associated time of travel, land use or disturbance, industrial safety impacts, job creation, and cost. The U.S. Air Force has informed DOE that it strongly opposes the Caliente-Chalk Mountain Corridor because it could adversely affect national security-related activities of the Nellis Air Force Range (now called the Nevada Test and Training Range). The State of Nevada and the City of Las Vegas have expressed specific concerns about shipments through or near the Las Vegas metropolitan area, which would occur if either the Jean or Valley Modified Corridor or the Caliente-Las Vegas, Apex/Dry Lake, or Sloan/Jean heavy-haul truck route was selected.

S.6 Environmental Consequences of the No-Action Alternative

Under the No-Action Alternative, DOE would terminate site characterization activities at the Yucca Mountain site. Long-term storage of spent nuclear fuel and high-level radioactive waste would continue at 77 sites.

DOE analyzed the potential impacts of two no-action scenarios: long-term storage with institutional controls (Scenario 1) and long-term storage with no effective institutional control after about 100 years (Scenario 2). The Department recognizes that neither of these scenarios is likely to occur if there is a decision not to develop a repository at Yucca Mountain, but any other scenarios would be too speculative for meaningful analysis. DOE therefore chose to include the two scenarios because they provide a basis for comparison to the impacts from the Proposed Action.

Activities at the Yucca Mountain site would be the same under either Scenario 1 or 2, as would impacts at the commercial and DOE sites during the first 100 years. After about 100 years and for as long as the 10,000-year analysis period and beyond, Scenario 2 assumes that the storage facilities at the 72 commercial sites and 5 DOE sites would deteriorate and that the radioactive materials in the spent nuclear fuel and high-level radioactive waste would eventually escape to the environment, contaminating the atmosphere, soil, surface water, and groundwater.

S.6.1 RECLAMATION AND DECOMMISSIONING AT THE YUCCA MOUNTAIN SITE

Under the No-Action Alternative, DOE would end characterization and construction activities at the Yucca Mountain Repository site and would complete site decommissioning and reclamation. Land ownership and control would revert to the original controlling authority. Adverse impacts to any resource would be unlikely as a result of these activities.

The overall impact of the No-Action Alternative would be the loss of approximately 4,700 jobs in the Yucca Mountain region of influence, out of approximately 840,000 jobs in the region. Most of the lost jobs would be in disciplines (construction, engineering, administration, support, etc.) that are not unique or unusual and are similar to those in the region. However, some of the jobs would be in unique disciplines (nuclear engineering, nuclear safety, etc.) that might not otherwise be needed in the region. Fatalities from industrial hazards would be unlikely, as would latent cancer fatalities from worker or public exposure to naturally occurring radionuclides released by decommissioning and reclamation activities. Resources important to Native American interests would be preserved, although the integrity of archeological sites and resources could be threatened by increased public access if roads were open and site boundaries were not secure.

S.6.2 CONTINUED STORAGE AT COMMERCIAL AND DOE SITES

The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would remain at the sites at which it is being generated and stored. For the EIS analysis, DOE divided the 72 commercial and 5 DOE sites among five regions of the country to organize the analysis into a framework that would promote an understanding of comparative impacts, and configured a single hypothetical site in each region. Such sites do not exist but are mathematical constructs for analytical purposes. Using this approach, DOE was able to estimate the potential release rate of the radionuclide inventory from the spent nuclear fuel and high-level radioactive waste, based on anticipated interactions of the environment (for example, rainfall and freeze-thaw cycles) with the concrete storage modules in which the nuclear materials would be stored.

The potential occupational and public health and safety impacts associated with the No-Action Alternative are described below. For purposes of this analysis, the potential occupational and public health and safety impacts are the most relevant for comparison with the impacts of the Proposed Action.

S.6.2.1 No-Action Scenario 1

Under this scenario, releases of contaminants to the ground, air, or water would be extremely small under normal conditions. Workers would perform routine industrial maintenance and maintenance unique to a nuclear materials storage facility to minimize releases of contaminants to the environment and exposures to workers and the public. These activities could result in worker exposures to industrial hazards, and worker and public exposures to radiological releases.

IMPACTS FROM NO-ACTION SCENARIO 1

Industrial hazards

- 2 worker fatalities in the first 100 years, and 320 in the next 9,900 years
- 760 fatalities in the public and worker population from worker commuting and transportation of maintenance materials over 10,000 years.

Radiological

- 3.0 latent cancer fatalities in exposed public population over 10,000 years (compared to 3.3 million from other causes in the areas immediately surrounding the 77 sites)
- 10 latent cancer fatalities in involved worker population over 10,000 years (compared to 37,600 from other causes)
- 16 latent cancer fatalities in involved and noninvolved worker population over 100 years, after which noninvolved workers would not be present at the site (compared to 18,800 from other causes)
- No radiological releases would be expected in the event of a severe accident (a postulated aircraft crash at the relatively low velocities encountered during takeoffs and landings) because of the integrity of the concrete storage modules. Consequences of impacts at higher velocities have not been evaluated by DOE for these Nuclear Regulatory Commission-licensed facilities.

S.6.2.2 No-Action Scenario 2

Under this scenario, after 100 years the facilities storing the materials at 72 commercial and 5 DOE sites would begin to deteriorate and would continue to do so over time. Eventually, radioactive materials from failed facilities and storage containers and exposed radioactive materials would contaminate the land surrounding the storage facilities, potentially rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. Contaminants would enter surface waters and groundwater, which would remain contaminated for the period required for the spent nuclear fuel and high-level radioactive waste materials to be depleted and contaminants to migrate out. Environmental concentrations of

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chemically toxic materials would be extremely low and would not result in adverse impacts. Released radioactive materials could produce chronic radiation exposures to the public, which could result in adverse health impacts. Intruders could incur severe radiation exposures, including fatal exposures. The number of people who would be affected by the migration of radioactive materials would be much greater in Scenario 2 than in Scenario 1.

IMPACTS FROM NO-ACTION SCENARIO 2

Industrial hazards

- 2 worker fatalities in the first 100 years and none in the next 9,900 years (workers not present at the site)
- 7 fatalities in the public and worker population from worker commuting and transportation of maintenance materials over 100 years

Radiological

- 3,300 latent cancer fatalities in exposed public population over 10,000 years (compared to 900 million expected from other causes along the 20 major waterways that would be contaminated)
- No latent cancer fatalities in involved worker population after 100 years
- No latent cancer fatalities in noninvolved worker population after 100 years
- Depending on the population at the site, between 3 and 13 latent cancer fatalities would be expected in the event of a severe accident (a postulated aircraft crash) at a degraded concrete storage module

S.6.2.3 Sabotage

Above-ground storage of spent nuclear fuel and high-level radioactive waste for 10,000 years would entail a continued risk of intruder access at each of the 77 sites. Sabotage could result in a release of radionuclides to the environment around the facility. Under Scenario 1, the analysis assumed that safeguards and security measures currently in place would remain in effect during the 10,000-year analysis period, thereby reducing the risk of sabotage.

As Nuclear Regulatory Commission licensees, the individual sites would be required to comply with Commission regulations and maintain the highest level of security as determined by the Commission, and any results from the reexamination of existing physical security and safeguard systems following the terrorist attack of September 11, 2001.

Because it is not possible to predict whether sabotage events would occur and, if they did, the nature of such events, DOE examined various accidents in this Final EIS, which provide an approximation of the consequences that could occur.

For Scenario 2, the storage of spent nuclear fuel and high-level radioactive waste for 10,000 years without institutional control would entail a greater risk of intruder access at the 77 sites than exists under current conditions. Due to the lack of institutional control and degraded facilities, sabotage could result in a release of radionuclides to the environment around the facility. The analysis assumed that safeguards and security measures would not be maintained after approximately the first 100 years. For the remaining 9,900 years of the analysis period, the cumulative risk of intruder attempts would increase. As the storage containers degraded, they would become more vulnerable to failure. Any amount of material released from its storage container could contaminate areas with radioactivity. Therefore, the risks of sabotage would increase substantially under this scenario in comparison to Scenario 1.

S.7 Cumulative Impacts of the Proposed Action

DOE evaluated cumulative short-term impacts from the construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain, and cumulative long-term impacts after repository closure. It also evaluated cumulative impacts from the transportation of spent nuclear fuel and high-level radioactive waste to the repository, including those from the construction and operation of a branch rail line or of an intermodal transfer station and highway upgrades for heavy-haul trucks.

> **CUMULATIVE IMPACTS**
>
> A cumulative impact is "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (Council on Environmental Quality Regulations, 40 CFR 1508.7). Cumulative impacts can result from individually minor but collectively potentially significant actions that occur over time.

An assessment of the environment around the Yucca Mountain site included the cumulative impacts of past and present actions in the area the Proposed Action would affect. Reasonably foreseeable future actions include the disposal of inventories of spent nuclear fuel and high-level radioactive waste that exceed the Proposed Action inventory of 70,000 MTHM, along with other Federal and non-Federal actions at the Nellis Air Force Range and the Nevada Test Site, DOE waste management activities, a private space launch facility, and a private intermodal transfer station, and private mineral and energy projects.

DOE could not reasonably predict future actions for the indefinite future. For that reason, DOE did not attempt to estimate cumulative impacts beyond about 100 years with the exception of impacts of radioactive materials reaching the groundwater and resulting in potential impacts to the public.

S.7.1 INVENTORY MODULES 1 AND 2

Section 114(d) of the Nuclear Waste Policy Act provides that the maximum amount allowed to be disposed of in a first repository until a second repository is in operation is 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. Comments that DOE received from the public during the scoping process for this EIS expressed the concern that more spent nuclear fuel and high-level radioactive waste would be generated than the 70,000 MTHM accounted for in the Proposed Action. In response to these comments, DOE evaluated the emplacement of the total projected inventory of commercial spent nuclear fuel and DOE spent nuclear fuel and high-level radioactive waste (Inventory Module 1) and emplacement of that total inventory plus the inventories of commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste (Inventory Module 2).

The emplacement of Inventory Module 1 or 2 at Yucca Mountain would require legislative action by Congress unless a second repository were in operation. In addition, the emplacement of commercial Greater-Than-Class-C and DOE Special-Performance-Assessment-Required wastes could require either legislative action or a determination by the Nuclear Regulatory Commission to classify these materials as high-level radioactive waste.

The emplacement of Inventory Module 1 or 2 would increase the size of the subsurface repository facilities and, thus, the amount of land disturbed. In addition, because more time would be required to emplace more materials (an additional 14 years for emplacement and perhaps another 6 years for closure under the lower-temperature repository operating mode) emplacement of Inventory Module 1 or 2 would

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INVENTORIES

Proposed Action
- 63,000 MTHM of commercial spent nuclear fuel
- 2,333 MTHM of DOE spent nuclear fuel
- 8,315 canisters of DOE high-level radioactive waste (equivalent of 4,667 MTHM)

Inventory Module 1
- 105,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 22,280 canisters of DOE high-level radioactive waste (equivalent of about 11,500 MTHM)

Inventory Module 2
- 105,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 22,280 canisters of DOE high-level radioactive waste (equivalent of about 11,500 MTHM)
- 2,000 cubic meters (72,500 cubic feet) of Greater-Than-Class-C waste
- 4,000 cubic meters (142,000 cubic feet) of Special-Performance-Assessment-Required waste

produce greater human health impacts to workers and to the public, increase energy use, create larger amounts of waste, and increase transportation impacts. Although such impacts would increase by as much as 70 percent with the emplacement of larger waste volumes, most of the impacts themselves would be small. The following paragraphs focus on occupational and public health and safety impacts related to the disposal of the additional inventories.

Occupational and Public Health and Safety

Impacts to Workers from Industrial Hazards. Up to 4 fatalities under Module 1 or 2 could occur compared to about 2 to 3 during the Proposed Action prior to closure. Most of the impacts would occur during the operations phase. Industrial safety impacts for injuries, illnesses, and lost workday cases for Module 1 or 2 would be about 30 to 40 percent greater than those for the Proposed Action.

Radiological Impacts to Workers. Most of the total worker radiation dose would result from activities during the operations and monitoring phase. As many as approximately 5 to 8 fatalities under Module 1 or 2 could occur in the worker population, compared to approximately 4 to 7 under the Proposed Action.

Radiological Impacts to the Public. Radiological health impacts to the public from construction, operation and monitoring, and closure of the repository would be small. The calculated likelihood that the maximally exposed individual would experience a latent cancer fatality is about 2.6×10^{-5} under Module 1 or 2, compared to 1.6×10^{-5} for the higher-temperature repository operating mode. Impacts for the lower-temperature operating mode would range from about the same as the higher-temperature operating mode to about twice the impacts of the higher-temperature mode. However, the estimated number of latent cancer fatalities for all operating modes for the Proposed Action or the Inventory Modules would be much less than 1.

Long-Term Radiological Impacts. Long-term cumulative impacts (impacts after closure at the repository) to public health would occur from radionuclides ultimately from Yucca Mountain, past weapons testing on the Nevada Test Site, and past, present, and future disposal of radioactive waste on the Nevada Test Site and near Beatty, Nevada. Cumulative impacts over 10,000 years from radionuclides released to groundwater would result in about 0.0003 latent cancer fatality over 10,000 years.

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S.7.2 OTHER FEDERAL AND NON-FEDERAL ACTIONS

This EIS evaluates the potential cumulative impacts of other Federal and non-Federal actions. The evaluation includes activities by local governments, private citizens, the Nellis Air Force Range, the Bureau of Land Management, the National Park Service, and the Nevada Test Site. It shows that earlier underground nuclear testing potentially results in long-term cumulative impacts due to potential groundwater contamination. Using conservative assumptions, the evaluation calculated the maximum potential dose from the radionuclides from underground testing to be 0.007 millirem per year. Therefore, the maximum cumulative impact of the Proposed Action in 10,000 years [using the mean impact at 18 kilometers (11 miles) from the repository] would be 0.00002 millirem per year (potential Yucca Mountain Repository impact) plus 0.007 millirem per year (potential underground testing impact), or 0.007 millirem per year.

S.7.3 TRANSPORTATION

The EIS analysis assumed the shipment of Inventory Module 1 or 2 to the repository would use the transportation routes described for the Proposed Action but would require almost twice as many shipments and an additional 14 years. This would result in increased industrial hazards, traffic fatalities, and latent cancer fatalities. For example, under the mostly legal-weight truck scenario, radiological and vehicle emission impacts from incident-free national transportation could increase from 12 to 24 occupational latent cancer fatalities, and estimated latent cancer fatalities in the general population could increase from 3 to 7 for the 38-year transportation of Inventory Module 1 or 2. Traffic-related fatalities from shipments of the modules would also be greater, increasing from 5 for the Proposed Action to 9 for Module 1 or 2. The incident-free impacts of the mostly rail scenario could be smaller because there would be fewer shipments.

National transportation of radiological materials from 1943 to 2047, not associated with the proposed repository would result in a total dose to affected transportation workers as high as 350,000 person-rem, which could result in about 140 latent cancer fatalities. These same activities would result in a total dose to the public of 340,000 person-rem, which could result in about 170 latent cancer fatalities. In addition, an estimated 97 traffic fatalities would result from the 104 years of transportation of radiological materials not associated with the Proposed Action.

The cumulative impacts to workers from transportation activities could be up to 160 or 180 latent cancer fatalities for Inventory Module 1 or 2, respectively. As many as 110 cumulative traffic fatalities would result from transporting radiological materials, including the inventory modules.

S.8 Cumulative Impacts of the No-Action Alternative

DOE analyzed the cumulative impacts of the No-Action Alternative with respect to Inventory Module 1. The Department did not analyze the cumulative impacts of the No-Action Alternative with respect to Inventory Module 2 because it did not have sufficient and readily available information about the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in that module to perform a meaningful analysis. Furthermore, this information could not be obtained without an exorbitant commitment of resources. However, information was sufficient to make the determination that there would be a small incremental increase in impacts over those of Module 1.

DOE estimated that about 6,400 concrete storage modules at the 72 commercial sites and three below-grade vaults at the DOE sites would be required to store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. In comparison, an additional 4,600 concrete storage modules (11,000 total) at the commercial sites and an additional five below-grade vaults (eight total) at the DOE sites would be required to store the entire inventory of Module 1.

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Impacts to Workers from Industrial Hazards. As many as 3 fatalities could occur at the storage and generator sites during the first 100 years under the No-Action Alternative with Inventory Module 1. This compares to 2 worker fatalities during the first 100 years with the 70,000-MTHM inventory. Over the next 9,900 years, approximately 490 fatalities could occur under No-Action Scenario 1 with Inventory Module 1, in comparison to 320 with the 70,000-MTHM inventory. No industrial hazard fatalities are projected for either the 70,000-MTHM inventory or Inventory Module 1 under No-Action Scenario 2 after the first 100 years because that scenario assumes there would be no workers at the sites.

Radiological Impacts to Workers. Approximately 43 latent cancer fatalities could occur at the storage and generator sites as a result of No-Action Scenario 1 with Inventory Module 1 over 10,000 years. This compares to 28 latent cancer fatalities in the worker population with the 70,000-MTHM inventory.

ESTIMATED NATIONAL TRANSPORTATION IMPACTS INVENTORY MODULE 1 OR 2 (for 38 years of operation)[a]

Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Incident-free latent cancer fatalities		
Involved worker	24	7
Public[b]	5	<2
Latent cancer fatalities from accidents		
Public	0.0004	0.0008
Traffic fatalities[c]	9	6
Latent cancer fatalities from maximum reasonably foreseeable accident	0.55	5
Frequency of occurrence per year	2.3×10^{-7}	2.8×10^{-7}

a. Modules 1 and 2 involve approximately the same number of shipments.
b. Potential latent cancer fatalities result from very small doses to a very large population.
c. Does not include 13 to 20 fatalities that could occur from repository workers commuting and transporting construction materials to the repository.

As with the 70,000-MTHM inventory, no latent cancer fatalities are projected in the worker population for Inventory Module 1 under No-Action Scenario 2 after 100 years because there would be no workers at the sites.

Radiological Impacts to the Public. About 5 latent cancer fatalities could occur in the exposed population over 10,000 years as a result of No-Action Scenario 1 with Inventory Module 1. This compares to about 4 latent cancer fatalities with the 70,000-MTHM inventory.

Under No-Action Scenario 2, the number of latent cancer fatalities could increase from about 3,300 in the exposed population with the 70,000-MTHM inventory over 10,000 years to about 3,700 in the same period with Inventory Module 1.

S.9 Management Actions to Mitigate Potential Adverse Environmental Impacts

DOE has identified the types of mitigation measures it could take to reduce or avoid potential adverse impacts from construction, operation and monitoring, and closure of the proposed repository. The type of actions identified to date include:

- Commitments included as part of the Proposed Action that would reduce impacts. These commitments are based on DOE's studies of Yucca Mountain that have been ongoing for more than 10 years.

- Actions that are under consideration in the event the U.S. Nuclear Regulatory Commission grants a license for the site. DOE would continue to evaluate these potential additional commitments. The analyses in the EIS do not take credit for these mitigations that may be decided on in the future.

In addition, DOE continues to evaluate additional measures to improve the long-term performance of the repository and to reduce uncertainties in estimates of performance. These measures include barriers to limit releases and transport of radionuclides, measures to control heat and moisture in the underground, and various designs to support operational considerations.

S.10 Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible or Irretrievable Commitments of Resources

The construction, operation and monitoring, and eventual closure of the proposed Yucca Mountain Repository and the associated transportation of spent nuclear fuel and high-level radioactive waste would have the potential to produce some environmental impacts that DOE could not completely mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources. For example:

- The permanent withdrawal of approximately 600 square kilometers (230 square miles) of land for the repository would be likely to prevent human use of the withdrawn lands for other purposes.

- Death or displacement of individual members of some animal species, including the desert tortoise, as a result of site clearing and vehicle traffic would be unavoidable.

- Injuries to workers or worker fatalities could result from facility construction, including accidents.

- Transportation of spent nuclear fuel and high-level radioactive waste would have the potential to affect workers and the public through exposure to radiation and vehicle emissions, and through traffic accidents.

Further, in the view of the Native American tribes in the Yucca Mountain region, the implementation of the proposed repository and its facilities would further degrade the environmental setting. Even after closure and reclamation, the presence of the repository would, from the perspective of Native Americans, result in an irreversible impact to traditional lands.

In addition, the Proposed Action would involve the following commitments of resources:

- Electric power, fossil fuels, and construction materials would be irreversibly committed to the project.

- DOE would use fossil fuel from the nationwide supply system to transport spent nuclear fuel and high-level radioactive waste to the repository.

S.11 Statutory and Other Applicable Requirements

Several statutes and regulations would apply to the licensing, development, operation, and closure of a geologic repository. These include the NWPA; the National Environmental Policy Act; the Atomic Energy Act; the Federal Land Policy and Management Act of 1976; site-specific public health and environmental radiation protection standards established by the Environmental Protection Agency; site-specific technical licensing regulations established by the Nuclear Regulatory Commission; and site suitability guidelines established by DOE. DOE is also subject to environmental protection and transportation requirements such as those set by the Clean Air Act; Clean Water Act; Hazardous Material Transportation Act; Emergency Planning and Community Right-to-Know Act of 1986; Comprehensive Environmental Response, Compensation, and Liability Act; Resource Conservation and Recovery Act; National Historic Preservation Act; Archaeological Resources Protection Act; Endangered Species Act; Nuclear Regulatory Commission regulations applicable to the transportation of radioactive materials; U.S. Department of Transportation regulations governing the transportation of hazardous materials; and applicable Nevada State statutes and regulations. In accordance with several statutes, DOE would need several new permits, licenses, and approvals from both Federal and State agencies to construct, operate and monitor, and eventually close the proposed Yucca Mountain Repository.

Under the authority of the Atomic Energy Act, DOE is responsible for establishing a comprehensive health, safety, and environmental program for its activities and facilities. The Department has established a framework for managing its facilities through the promulgation of regulations and the issuance of DOE Orders. In general, DOE Orders set forth policies, programs, and procedures for implementing policies. Many DOE Orders contain specific requirements in the areas of radiation protection, nuclear safety and safeguards, and security of nuclear material. Because the Nuclear Regulatory Commission is authorized to license the proposed Yucca Mountain repository, DOE issued Order 250.1 exempting such a repository from compliance with provisions of DOE Orders that overlap or duplicate Nuclear Regulatory Commission licensing requirements.

DOE has interacted with agencies authorized to issue permits, licenses, and other regulatory approvals, as well as those responsible for protecting such significant resources as endangered species, wetlands, or historic properties. DOE also has coordinated with the affected units of local government, U.S. Nuclear Regulatory Commission, U.S. Air Force, U.S. Navy, U.S. Department of Agriculture, U.S. Department of Transportation, U.S. Environmental Protection Agency, Department of the Interior including its Bureaus (U.S. Fish and Wildlife Service, National Park Service, and Bureau of Land Management), the Council on Environmental Quality, Nevada Department of Transportation, and Native American tribes. In addition, DOE provided a copy of the Draft EIS and Supplement to the Draft EIS to these agencies and entities.

S.12 Conclusions

S.12.1 MAJOR CONCLUSIONS OF THE EIS

In general, the Proposed Action would cause small, short-term public health impacts due primarily to the transportation of spent nuclear fuel and high-level radioactive waste from the existing commercial and DOE sites to the proposed repository. The specific impacts at the repository site would be very small as indicated in Table S-1. The transportation impacts would be associated mainly with nonradiological traffic fatalities and very low radiological doses to members of the public from the routine transportation of radioactive materials.

The EIS analysis demonstrated that the long-term performance of the proposed repository over 10,000 years would result in a mean peak annual dose of 0.00002 millirem to a reasonably maximally exposed individual hypothetically located 18 kilometers (11 miles) from the repository. The analysis of a human intrusion event occurring at 30,000 years indicated a mean peak annual dose of 0.002 millirem to the reasonably maximally exposed individual at the same location.

As a result of this evaluation, DOE does not expect the repository to result in impacts to public health beyond those that could result from the prescribed radiation exposure and activity concentration limits in 40 CFR Part 197 and 10 CFR Part 63 during the 10,000-year period after closure.

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IMPACTS FROM THE PROPOSED ACTION

Nonradiological hazards
- 2 to 3 worker fatalities from repository construction, operation and monitoring, and closure
- 2 to 4 worker fatalities from traffic accidents while commuting to and from the repository
- 6 to 14 traffic fatalities associated with the transportation of construction materials and public involved in accidents with commuters
- 3 to 5 traffic fatalities associated with the shipment of spent nuclear fuel and high-level radioactive waste
- 2 to 3 fatalities in the general population due to latent effects of vehicle emissions (transportation of spent nuclear fuel and high-level radioactive waste, construction materials, and commuters)

Radiological
- 4 to 7 latent cancer fatalities to workers at the repository
- 3 to 12 latent cancer fatalities to workers during the loading and transport of spent nuclear fuel and high-level radioactive waste
- 0.5 to 2 latent cancer fatalities in the general population from releases of naturally occurring radon from the repository
- 0.8 to 2.5 latent cancer fatalities in the general population from loading and transport of spent nuclear fuel and high-level radioactive waste
- Essentially zero long-term latent cancer fatalities within 10,000 years associated with the repository performance

These values represent the range of impacts for all operating modes, transportation scenarios, and implementing alternatives.

Under the No-Action Alternative, latent cancer fatalities would be unlikely in the short term in either the worker or public populations. These short-term impacts would be very similar to those associated with the Proposed Action. In addition, under the No-Action Alternative there would be no impacts associated with the transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository. However, the obligation to store these materials continually in a safe configuration would become the responsibility of future generations.

There could be large public health and environmental consequences under the No-Action Alternative if there were no effective institutional control, causing storage facilities and containers to deteriorate and radioactive contaminants from the spent nuclear fuel and high-level radioactive waste to enter the environment. In such circumstances, there would be widespread contamination at the 72 commercial and 5 DOE sites across the United States, with resulting human health impacts.

Table S-1 compares the potential impacts associated with the Proposed Action to those associated with the No-Action Alternative.

S.12.2 DISTINCTIONS BETWEEN IMPACTS OF THE PROPOSED ACTION AND NO-ACTION ALTERNATIVE

The analysis of the potential short-term environmental impacts associated with the Proposed Action and with the two No-Action scenarios revealed that the impacts would be small and related to health and safety and to socioeconomics.

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Table S-1. Impacts associated with the Proposed Action and No-Action Alternative.[a] (page 1 of 4).

	Flexible design potential operating modes–range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation		(100 years)	Scenario 1	Scenario 2
Land use and ownership	Small; the flexible design range of disturbed land is from 4.3 km^2[(b)] to about 6.0 km^2 of the 600 km^2 that comprise the analyzed withdrawal area	Small to moderate; 0 to about 20 km^2 of land disturbed for new transportation routes; Air Force identified Nellis Air Force Range conflicts for some routes; some routes pass close to or through Wilderness Study Areas; some corridors could directly impact Native Americans and Indian reservations; and one corridor could conflict with the Ivanpah Airport construction and operation	Small; potential for limited access into the area; the only surface features remaining would be markers	Small; storage would continue at existing sites	Small; storage would continue at existing sites	Large; potential contamination of 0.04 to 0.4 km^2 surrounding each of the 72 commercial and 5 DOE sites
Air quality	Small; releases and exposures well below regulatory limits (less than 6 percent of limits)	Small; releases and exposures below regulatory limits; pollutants from vehicle traffic and trains would be small in comparison to other national vehicle and train traffic; Clean Air Act General Conformity Requirements might apply in Clark County Nevada	Very small, 5.3×10^{-10} latent cancer fatalities peak effect	Small; releases and exposures well below regulatory limits	Small; releases and exposures well below regulatory limits	Small; degraded facilities would preclude large atmospheric releases
Hydrology (groundwater and surface water)	Groundwater–small; water demand (230 to 290 acre-feet[c] per year) well below lowest estimate of the groundwater basin's perennial yield (580 acre-feet)	Small; withdrawal of up to 710 acre-feet from multiple wells and hydrographic areas over about 4 years	Small amounts of contamination of groundwater in Amargosa Valley during the first 10,000 years. Contamination is several hundred thousand times less than the groundwater protection standard in 40 CFR 197	Small; usage would be small in comparison to other site use	Small; usage would be small in comparison to other site use	Large; potential for radiological contamination of groundwater around 72 commercial and 5 DOE sites
	Surface water–small; new land disturbance of 2.8 to 4.5 square kilometers would result in minor changes to runoff and infiltration rates; floodplain assessment concluded impacts would be small	Small; minor changes to runoff and infiltration rates; all rail corridors pass through areas of identified 100-year flood zones, additional floodplain assessments would be performed in the future as necessary	Small; minor changes to runoff and infiltration rates	Small; minor changes to runoff and infiltration rates	Small; minor changes to runoff and infiltration rates	Large; potential for radiological releases and contamination of drainage basins downstream of 72 commercial and 5 DOE sites (concentrations potentially exceeding current regulatory limits)

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative.[a] (page 2 of 4).

Resource area	Flexible design potential operating modes–range of impacts: Short-term (through closure): Repository	Short-term (through closure): Transportation	Long-term (after closure, to 10,000 years)	No-Action Alternative: Short-term (100 years)	Long-term (100 to 10,000 years): Scenario 1	Long-term (100 to 10,000 years): Scenario 2
Biological resources and soils	Small to moderate; loss of about 4.3 km^2 to 6.0 km^2 of desert soil, habitat, and vegetation; adverse impacts to individual threatened desert tortoises (not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; wetlands assessment concluded impacts would be small	Small to moderate; loss of 0 to 20 km^2 of desert soil, habitat, and vegetation for heavy-haul routes and rail corridors; adverse impacts to individual threatened desert tortoises (not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; additional wetlands assessments would be performed in the future as necessary prior to any construction	Small; slight increase in temperature of surface soil directly over the repository for 10,000 years resulting in a potential temporary shift in plant and animal communities in this small area (about 8 km^2)	Small; storage would continue at existing sites	Small; storage would continue at existing sites	Large; potential adverse impacts at each of the 77 sites from subsurface contamination of 0.04 to 0.4 km^2
Cultural resources	Small to moderate; repository development would disturb up to about 4.5 km^2 of previously undisturbed land; mitigation measures would avoid or minimize damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Small to moderate; loss of 0 to 20 km^2 of land disturbed for new transportation routes; mitigation measures would avoid or minimize damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Small; potential for limited access into the area; opposing Native American viewpoint	Small; storage would continue at existing sites; limited potential of disturbing sites	Small; storage would continue at existing sites; limited potential of disturbing sites	Small; no construction or operation activities; no impacts
Socioeconomics	Small; estimated peak total employment of 3,400 occurring in 2006 would result in less than a 1 percent increase in composite regional employment; therefore, impacts would be small. Estimated peak direct employment for the repository during construction would be approximately 1,900 in 2006.	Small; employment increases would range from less than 1 percent to 4.9 percent (use of intermodal transfer station in Lincoln County) of employment in affected counties	Small; no workers, no impact	Small; population and employment changes would be small compared to totals in the regions	Small; population and employment changes would be small compared to totals in the regions	Small; no workers; no impacts
Occupational and public health and safety						
Public						
Radiological[d]						
MEI (probability of an LCF)	1.6×10^{-5} to 3.1×10^{-5}	1.4×10^{-4} to 1.2×10^{-3}	4×10^{-10} to 4×10^{-9} at the boundary of the controlled area (approximately 18 km south of the repository)	4.3×10^{-6}	1.3×10^{-6}	(e)
Population (LCFs)	0.46 to 2.0	0.61 to 2.5	2×10^{-6} to 3×10^{-4}	0.41	3	3,300[f]
Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits	1.6 to 2.8[g]	Small; exposures well below regulatory limits or guidelines	Small; exposures well below regulatory limits or guidelines	Small; exposures well below regulatory limits or guidelines	Moderate to large; substantial increases in releases of hazardous substances in the spent nuclear fuel and high-level radioactive waste and exposures to the public

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Table S-1. Impacts associated with the Proposed Action and No-Action Alternative.[a] (page 3 of 4).

Resource area	Flexible design potential operating modes–range of impacts: Short-term (through closure): Repository	Transportation	Long-term (after closure, to 10,000 years)	No-Action Alternative: Short-term (100 years)	Long-term (100 to 10,000 years): Scenario 1	Scenario 2
Occupational and public health and safety (continued)						
Workers (involved and noninvolved)						
Radiological (LCFs)	4.0 to 6.8	3.2 to 11.7	No workers, no impacts	16	10	No workers, no impacts
Nonradiological fatalities (includes commuting traffic fatalities)	2.0 to 3.3	12 to 23[h]	No workers, no impacts	9	1,080	No workers, no impacts
Accidents						
Public						
Radiological						
MEI (probability of an LCF)	2.9×10^{-13} to 1.9×10^{-5}	0.0015 to 0.015	Not applicable	No impacts	No impacts	Not applicable
Population (LCFs)	1.4×10^{-11} to 1.1×10^{-2}	0.55 to 5	Not applicable	No impacts	No impacts	3 to 13
Workers	Large; for some unlikely accident scenarios workers would likely be severely injured or killed	Large; for some unlikely accident scenarios workers would likely be severely injured or killed	No workers, no impacts	Large; for some unlikely accident scenarios workers would likely be severely injured or killed	Large; for some unlikely accident scenarios workers would likely be severely injured or killed	Small; no workers; no impacts
Noise/Ground Vibration	Small; impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels–controls and protection used as necessary	Small to moderate; transient and not excessive, less noise than 90 dBA[i]; ground vibration infrequent and less than 88 dBV at 25 m	Small; no activities, therefore, no noise or ground vibration	Small; transient and not excessive, less than 90 dBA	Small; transient and not excessive, less than 90 dBA	Small; no activities, therefore, no noise
Aesthetics	Small; low adverse impacts to aesthetic or visual resources in the area. There may be increase in lighting impacts due to lighting associated with the ventilation system	Small; possible temporary and transient; conflict with visual resource management goals for Wilson Pass Option of the Jean rail corridor; and discernible impacts from the Caliente Intermodal transfer facility near Kershaw-Ryan State Park.	Small; only surface features remaining would be markers	Small; storage would continue at existing sites; expansion as needed	Small; storage would continue at existing sites; expansion as needed	Small; aesthetic value decreases as facilities degrade
Utilities, energy, materials, and site services	Small; use of materials would be very small in comparison to amounts used in the region; electric power delivery system to the Yucca Mountain site would have to be enhanced	Small; use of materials and energy would be small in comparison to amounts used nationally	Small; no use of materials or energy	Small; materials and energy use would be small compared to total site use	Small; materials and energy use would be small compared to total site use	Small; no use of materials or energy
Management of site-generated waste and hazardous materials	Small; radioactive and hazardous waste generated would be a few percent of existing offsite capacity; other wastes would be managed onsite	Small; waste generated would be a fraction of existing offsite capacity	Small; no waste generated or hazardous materials used	Small; waste generated and materials used would be small compared to total site generation and use	Small; waste generated and materials used would be small compared to total site generation and use	Small; no waste generated or hazardous materials used

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Table S-1. Impacts associated with the Proposed Action and No-Action Alternative.[a] (page 4 of 4).

Resource area	Flexible design potential operating modes – range of impacts: Short-term (through closure) – Repository	Flexible design potential operating modes – range of impacts: Short-term (through closure) – Transportation	Flexible design potential operating modes – range of impacts: Long-term (after closure, to 10,000 years)	No-Action Alternative: Short-term (100 years)	No-Action Alternative: Long-term (100 to 10,000 years) – Scenario 1	No-Action Alternative: Long-term (100 to 10,000 years) – Scenario 2
Environmental justice	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	Small; no disproportionately high and adverse impacts to minority or low-income populations	Small; no disproportionately high and adverse impacts to minority or low-income populations	Large; potential for disproportionately high and adverse impacts to minority or low-income populations

a. Ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

b. km^2 = square kilometers; to convert to acres, multiply by 247.1.

c. To convert acre-feet to cubic meters, multiply by 1233.49.

d. LCF = latent cancer fatality; MEI = maximally exposed individual.

e. With no effective institutional controls, the maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death would be caused by acute direct radiation exposure.

f. Downstream exposed population of approximately 3.9 billion over 10,000 years.

g. Nonradiological fatalities due to exhaust emissions health effects from spent nuclear fuel and high-level radioactive waste transportation, including loadout; exhaust emissions health effects from commuter and materials transportation for repository construction, operation, and closure; and rail line or heavy-haul truck/intermodal transfer station construction, maintenance, and operation.

h. Nonradiological traffic fatalities from spent nuclear fuel and high-level radioactive waste transportation and commuter traffic fatalities. As many as 10 to 17 of these fatalities could be members of the public.

i. dBA = *A-weighted decibels*, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

For the Proposed Action, using DOE's preferred transportation mode (mostly rail), about 24 to 38 latent cancer fatalities and nonradiological fatalities would be associated with the transportation of spent nuclear fuel and high-level radioactive waste and the construction, operation and monitoring, and closure of the repository at Yucca Mountain. Depending on the transportation mode, transportation impacts of the Proposed Action would result in about 4 latent cancer fatalities and 14 to 23 nonradiological fatalities. Construction and operation of the repository would result in 4 to 8 latent cancer fatalities and 2 to 3 nonradiological fatalities, depending on the repository operating mode.

In comparison, there would be about 25 latent cancer fatalities and nonradiological fatalities from the No-Action Alternative (both scenarios) during the first 100 years. For both scenarios, there would be about 7 nonradiological fatalities from commuting and shipping construction materials and about 16 latent cancer fatalities and 2 nonradiological fatalities from construction and operations.

Short-term socioeconomic impacts would occur in the Yucca Mountain region and at the existing storage locations under the Proposed Action; impacts under the No-Action Alternative would occur only in the Yucca Mountain region. Under the Proposed Action, there would be nearly 2,700 new jobs in the three-county area around Yucca Mountain (Clark, Lincoln, and Nye Counties). In addition, under the Proposed Action there would be lost jobs at each of the sites across the United States as spent nuclear fuel and high-level radioactive waste was removed. Under the No-Action Alternative, there would be a loss of about 4,700 direct and indirect jobs in the three-county area around Yucca Mountain once reclamation was completed. There would be no short-term socioeconomic impacts at the storage sites under the No-Action Alternative.

The potential long-term (postclosure to 10,000 years) environmental impacts of the Proposed Action and No-Action Scenario 1 (continued institutional control) would also be small. Under the Proposed Action, there would be virtually no latent cancer fatalities (much less than 1) over 10,000 years. In addition, there would be a potential for very small impacts to vegetation and animals over the repository area as soil surface temperatures increased. Under the No-Action Scenario 1, there would be about 13 latent cancer fatalities and about 1,100 nonradiological fatalities associated with the construction and replacement of storage facilities, monitoring of facilities, worker commuting, and transportation of construction materials. Small impacts to other resources (for example, socioeconomics, biological resources, utilities and services) would occur.

There would be differences in the potential long-term environmental impacts under No-Action Scenario 2 (no institutional control after 100 years) compared to No-Action Scenario 1. Under No-Action Scenario 2, there would be about 3,300 latent cancer fatalities over 10,000 years as storage facilities across the United States degraded and radionuclides from spent nuclear fuel and high-level radioactive waste reached and contaminated the environment. There would be no fatalities associated with transportation, construction, or operation because those activities would not occur after the presumed loss of institutional control.

S.12.3 AREAS OF CONTROVERSY

The Department acknowledges that areas of controversy exist regarding the Proposed Action and the analyses in this EIS. Areas of controversy were identified during the public interaction processes. Many of these are not resolvable because they reflect either differing points of view or irreducible uncertainties in predicting the future. However, the Department has considered these areas in the development of this Final EIS. Other issues raised by the public are summarized in Section S.4.2.4.

Native American Viewpoint

Disagreement exists about the nature of the repository as it might impact elements of the natural and cultural environment that are of concern to Native American tribes.

Perceived Risk and Stigma
Disagreement exists concerning whether the perception of risk and stigma cause behavioral changes, the ability of researchers to predict future human behavior based on perception of risk and stigma, and the capability to reliably predict economic effects of any such stigma.

High-Level Radioactive Waste—Equivalency of Metric Tons of Heavy Metal
Disagreement exists about the method for calculating the amount of MTHM in a canister of high-level radioactive waste. This would affect the number of canisters that could be disposed of under the Proposed Action.

Engineered Barriers
Disagreement exists about how much reliance should be placed on engineered barriers versus natural barriers to achieve waste isolation in a geologic repository.

Transportation
Disagreement exists regarding factors relevant to the analyses of the potential environmental impacts from the transportation of spent nuclear fuel and high-level radioactive waste including for example, the need for community- and highway-specific information, and assumptions and input information used in the analyses.

Evaluation of Long-Term Performance
Disagreement exists regarding the ability to predict long-term performance for 10,000 years or more. Uncertainties associated with complex natural systems and engineered barrier behaviors and the use of computer models that are unable to rely on the results of long-term testing raise questions about the ability of the Department to predict repository performance.

S.12.4 ISSUES TO BE RESOLVED

There are no issues that remain to be resolved for this Final EIS to accompany any site recommendation.

However, prior to initiation of the Proposed Action to construct, operate and monitor, and eventually close a repository at Yucca Mountain, three primary issues would require resolution:

1. The Yucca Mountain site must be designated under the NWPA for development of a geologic repository.

2. If the site was designated, the Department would have to complete selection of the design features required to support a Licence Application to the Nuclear Regulatory Commission.

3. If the site was designated, the Department would have to make transportation-related decisions required to support implementation of the Proposed Action. Such decisions would include the choice of a national mode of transportation outside of Nevada (mostly legal-weight truck or mostly rail), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an intermodal transfer station in Nevada.

S.13 Detailed Nevada Transportation Maps

Figures S-23 through S-35 are maps that show the candidate rail corridors and heavy-haul truck routes in Nevada. Figures S-23 and S-30 are index maps for rail and heavy-haul routes, respectively. That is, they identify the relationships of the more detailed maps that follow them. Figure S-23 shows the relationship of six detailed maps (Figures S-24 through S-29), each of which shows potential corridors (or portions of corridors) for the five candidate rail corridors, including variations. Similarly, Figure S-30 shows the relationship of four detailed maps (Figures S-31 through S-34), each of which shows candidate heavy-haul truck routes (or portions of routes). Finally, Figure S-35 is a legend for all of the detailed maps.

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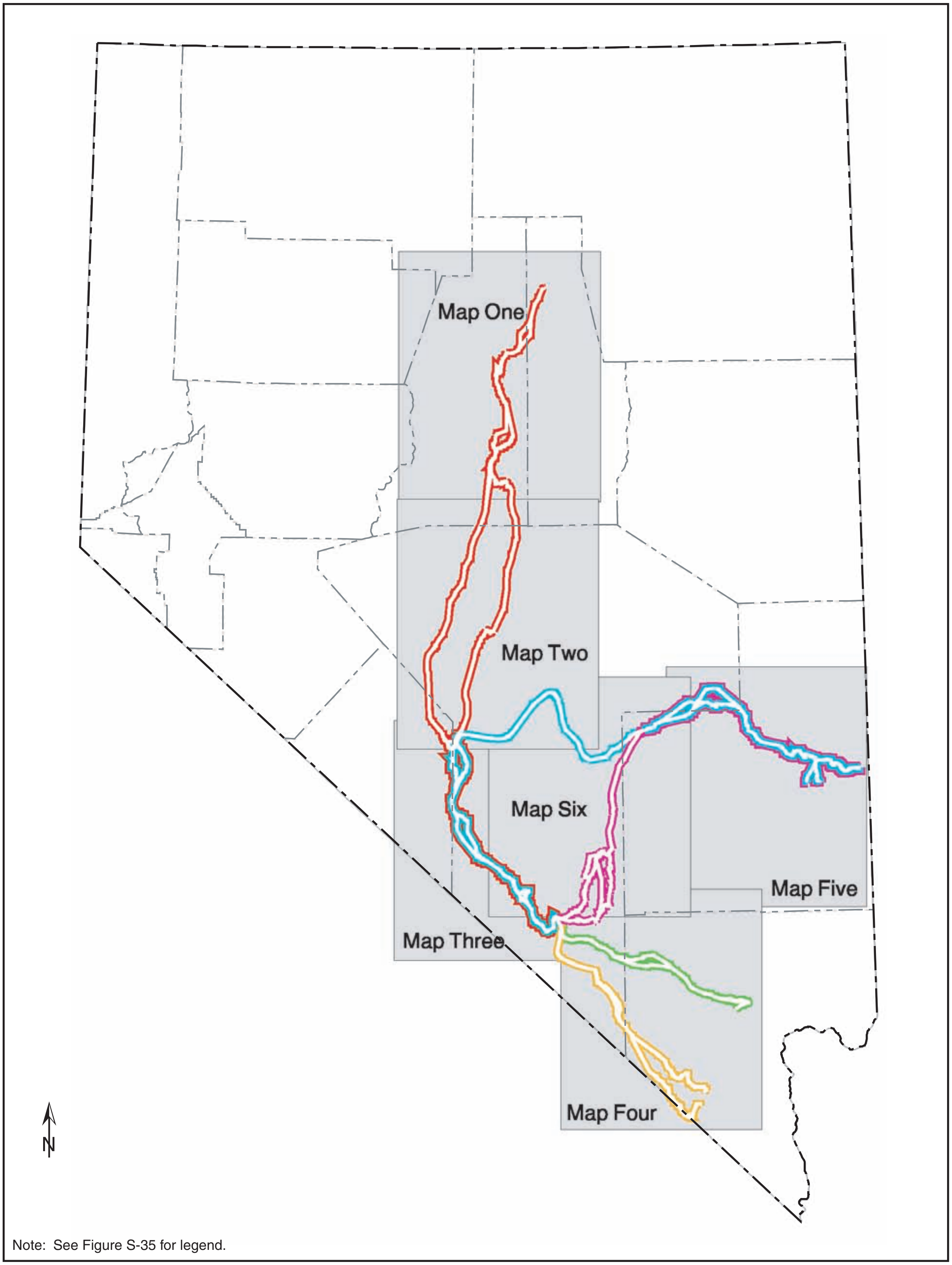

Figure S-23. Candidate rail corridors (Index).

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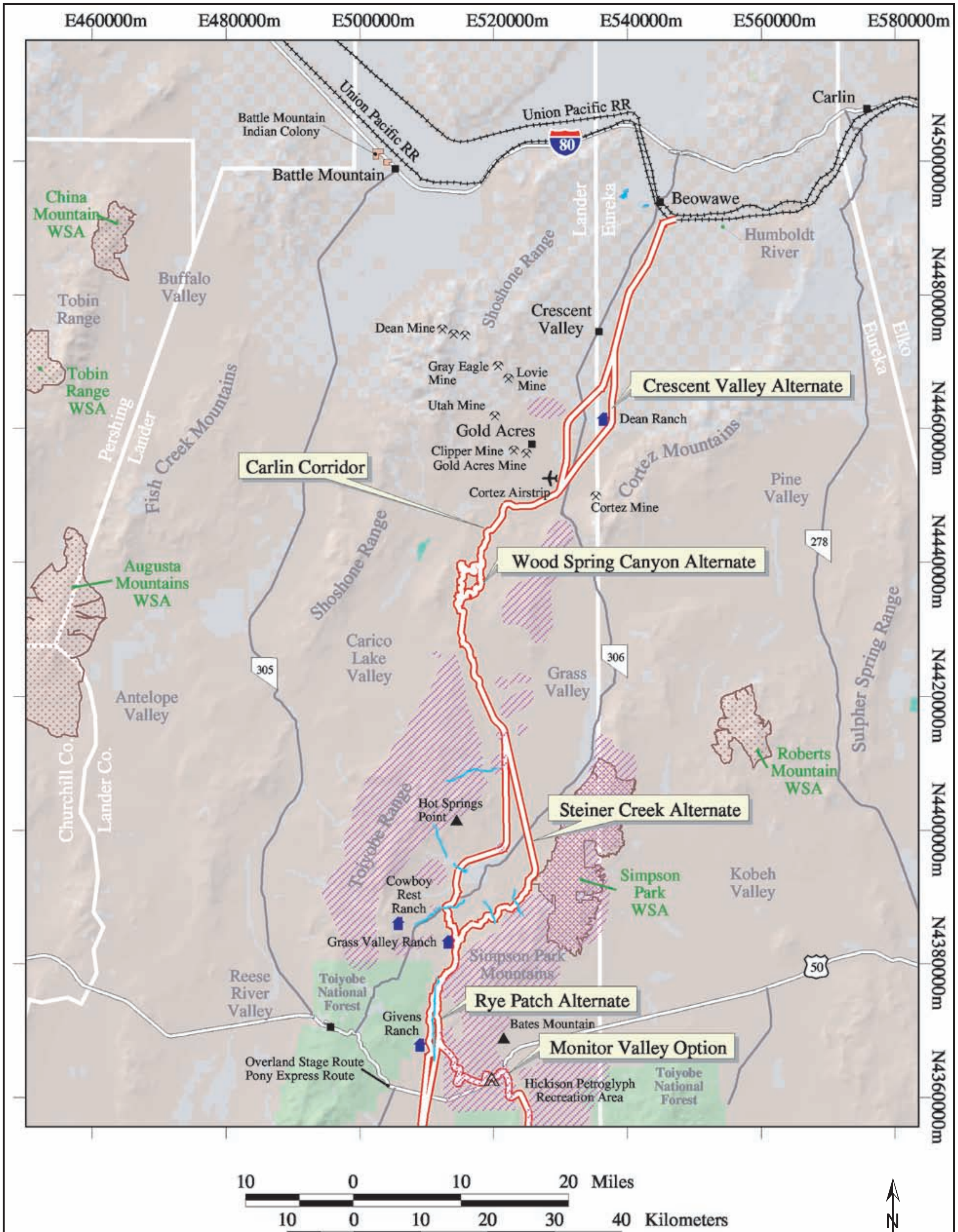

Note: See Figure S-35 for legend.

Figure S-24. Candidate rail corridors (Map One).

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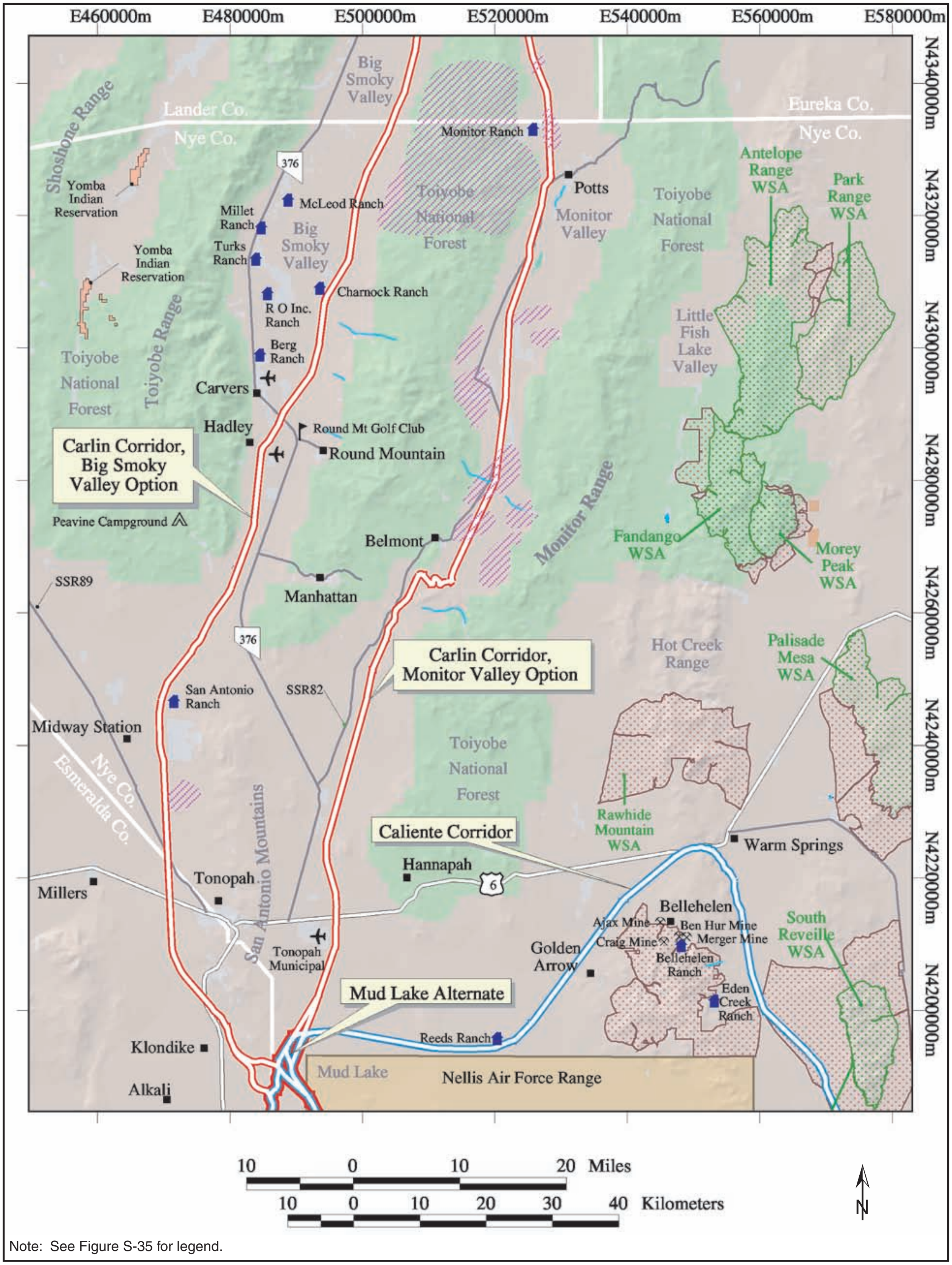

Figure S-25. Candidate rail corridors (Map Two).

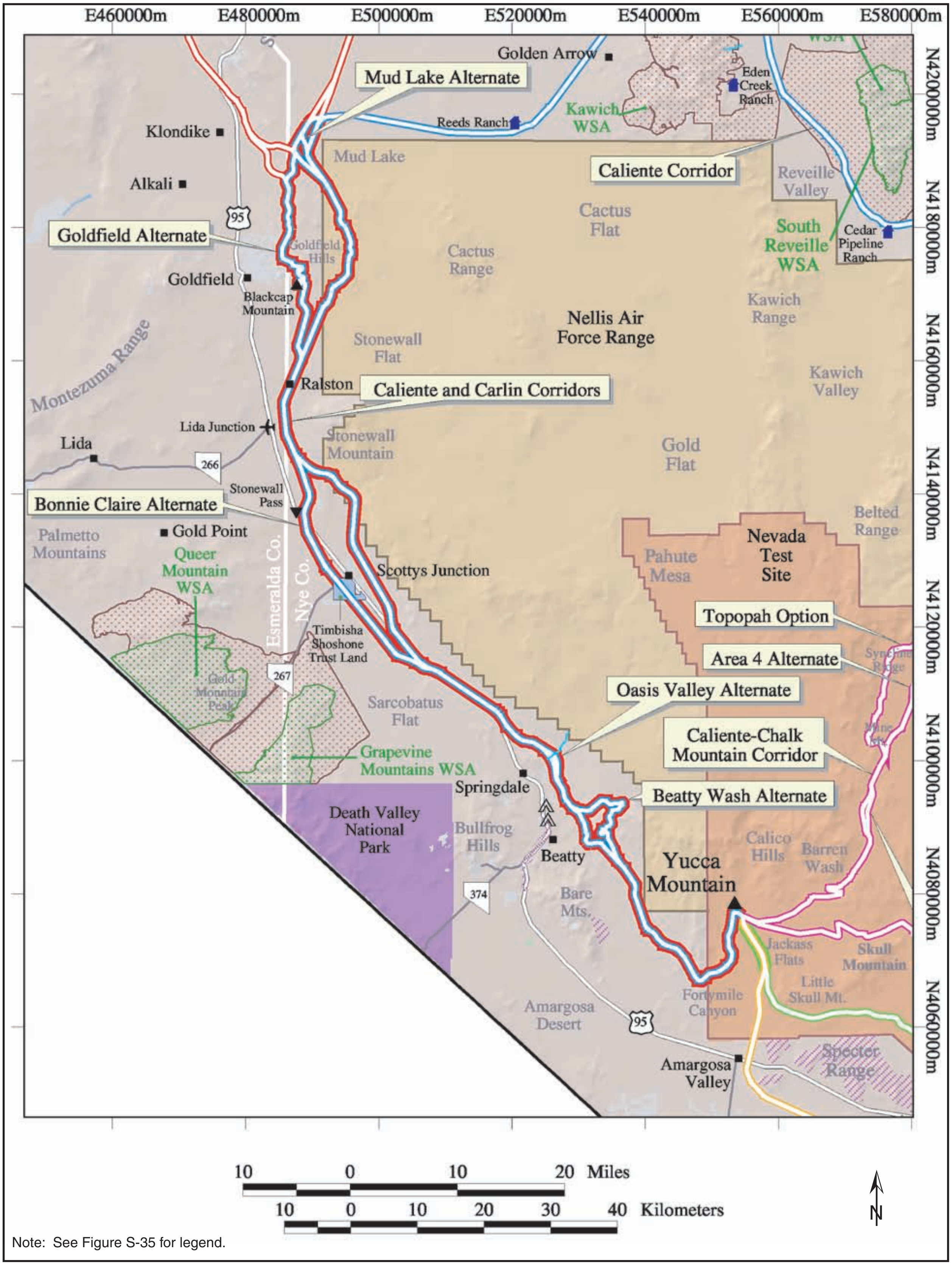

Figure S-26. Candidate rail corridors (Map Three).

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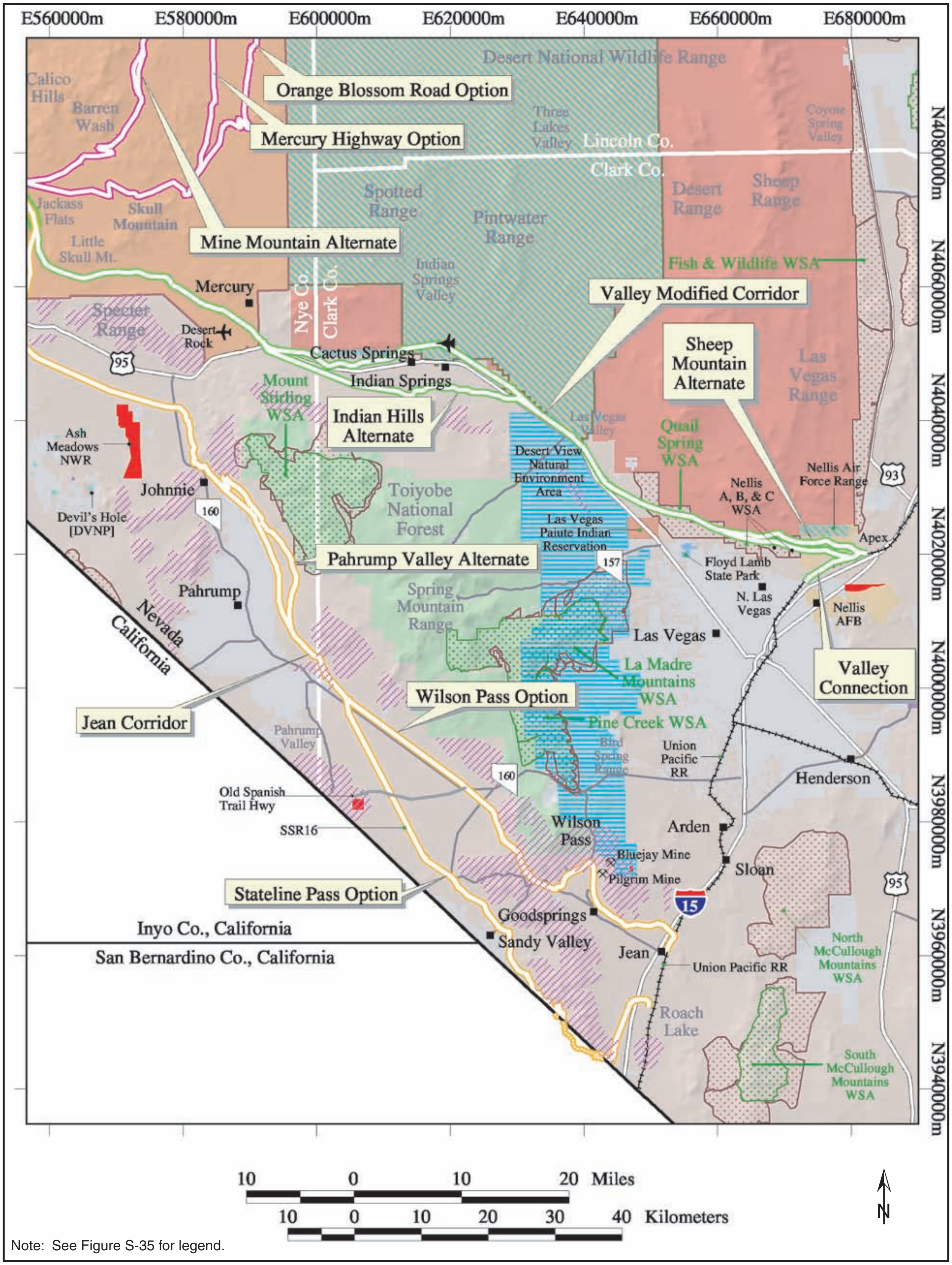


Figure S-27. Candidate rail corridors (Map Four).

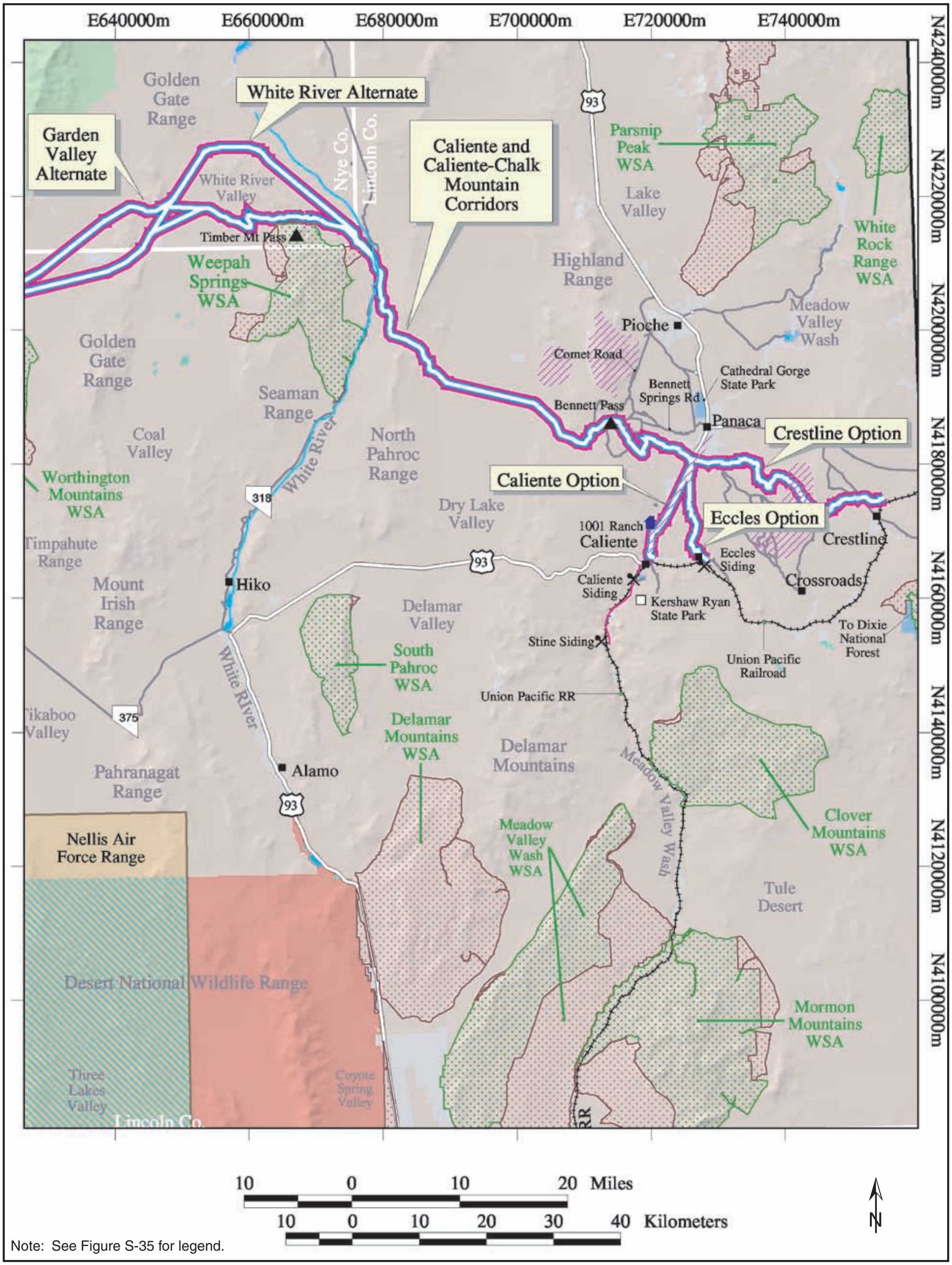
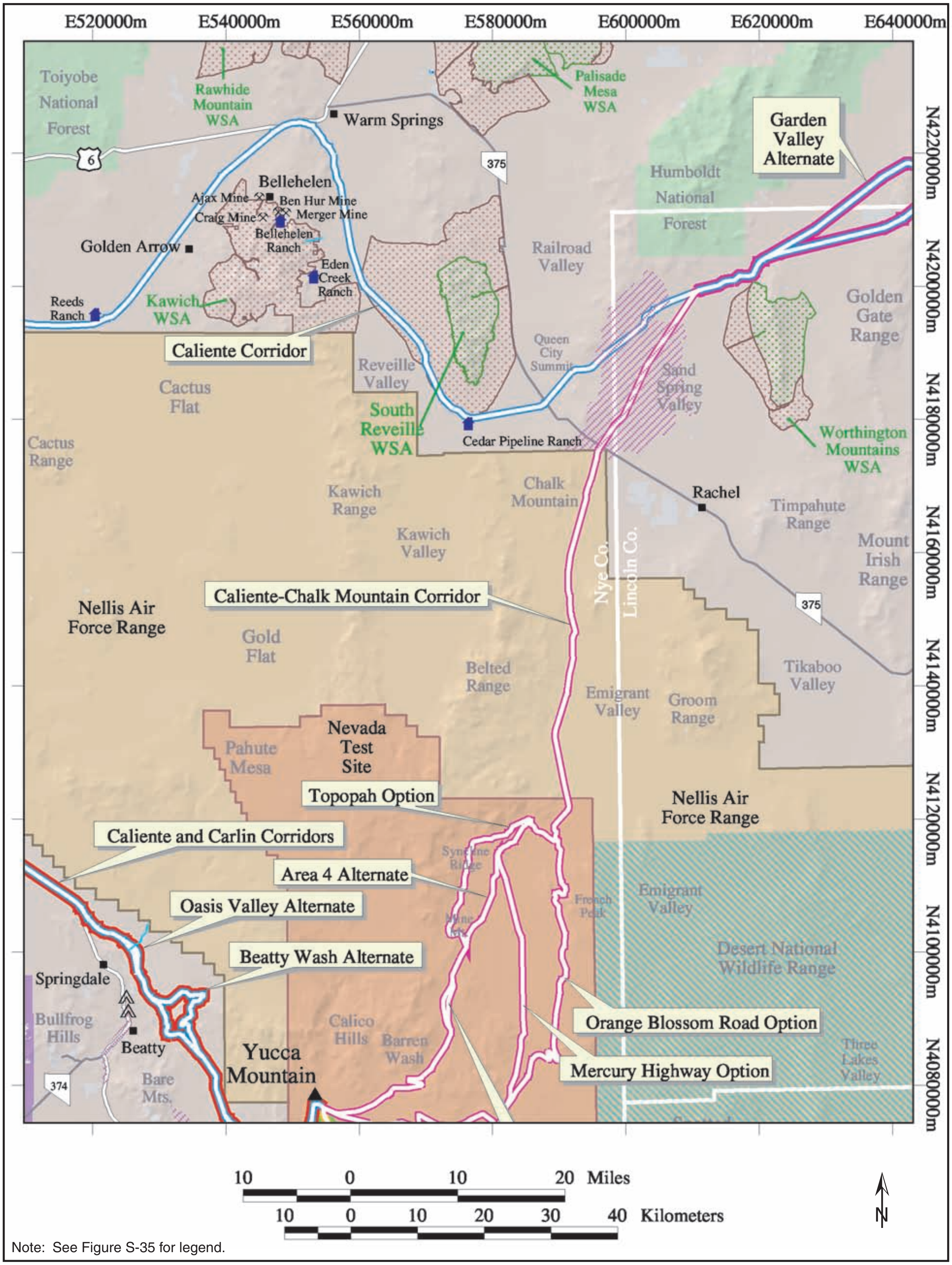


Figure S-28. Candidate rail corridors (Map Five).



Note: See Figure S-35 for legend.

Figure S-29. Candidate rail corridors (Map Six).

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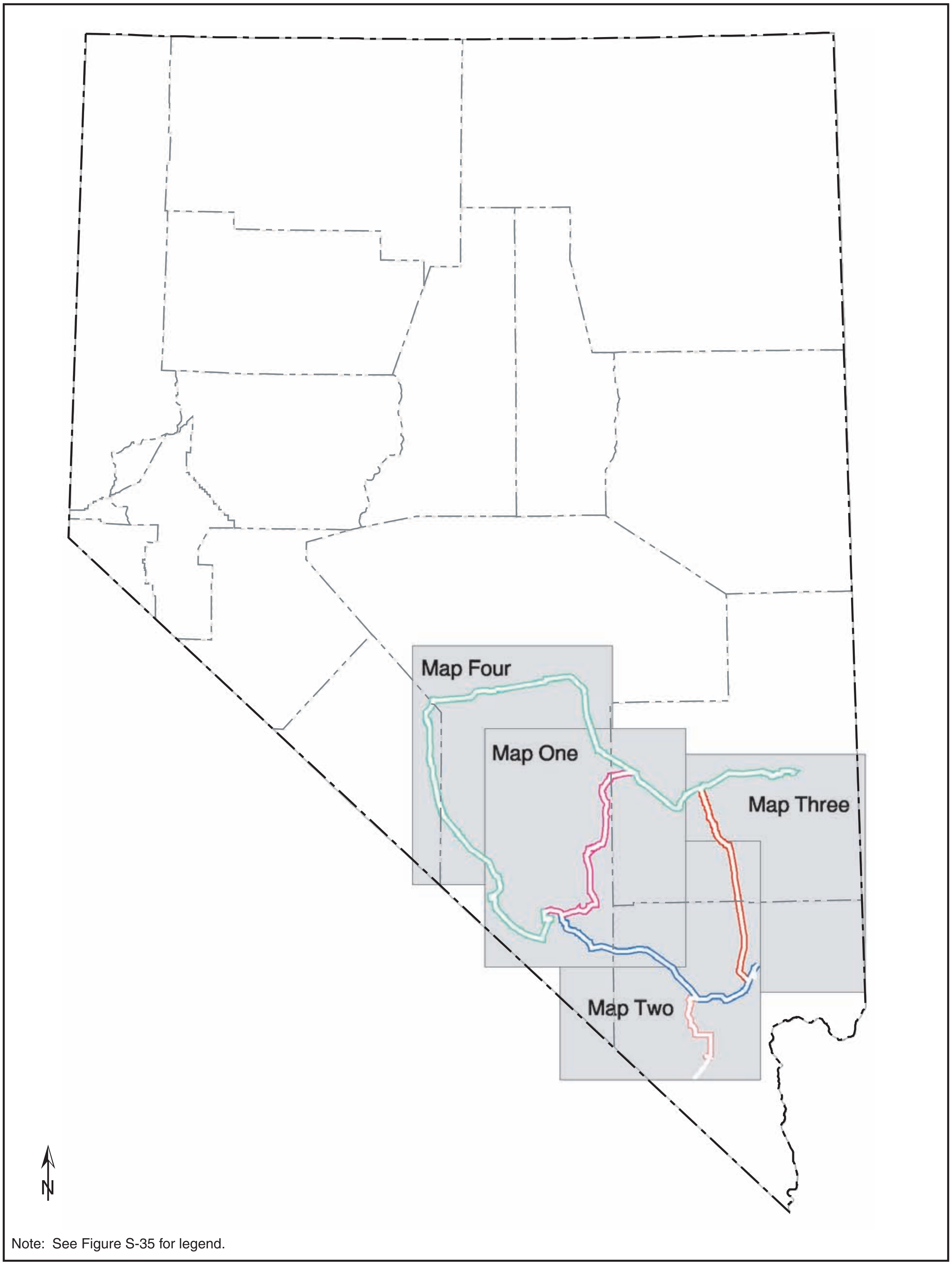
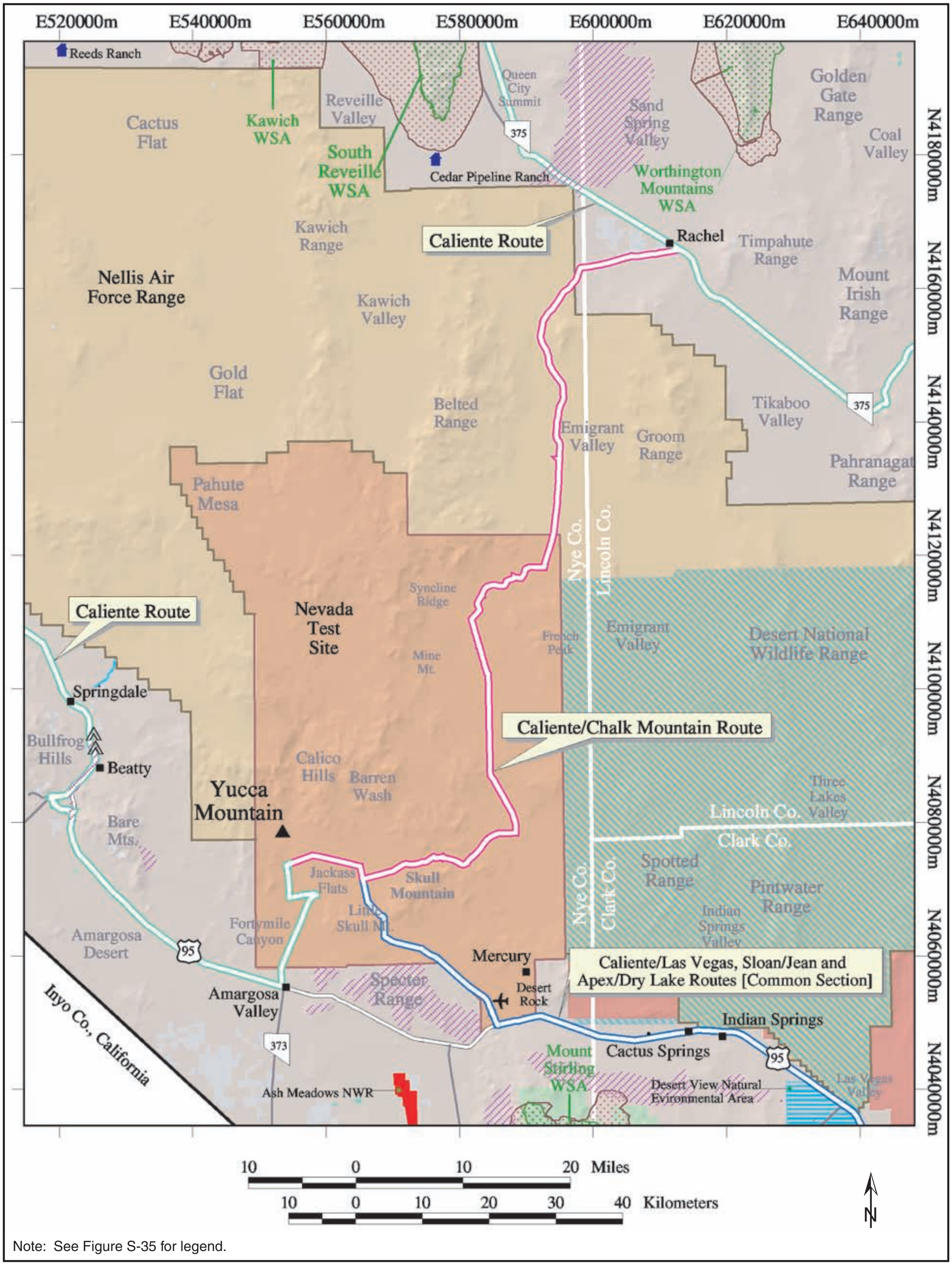
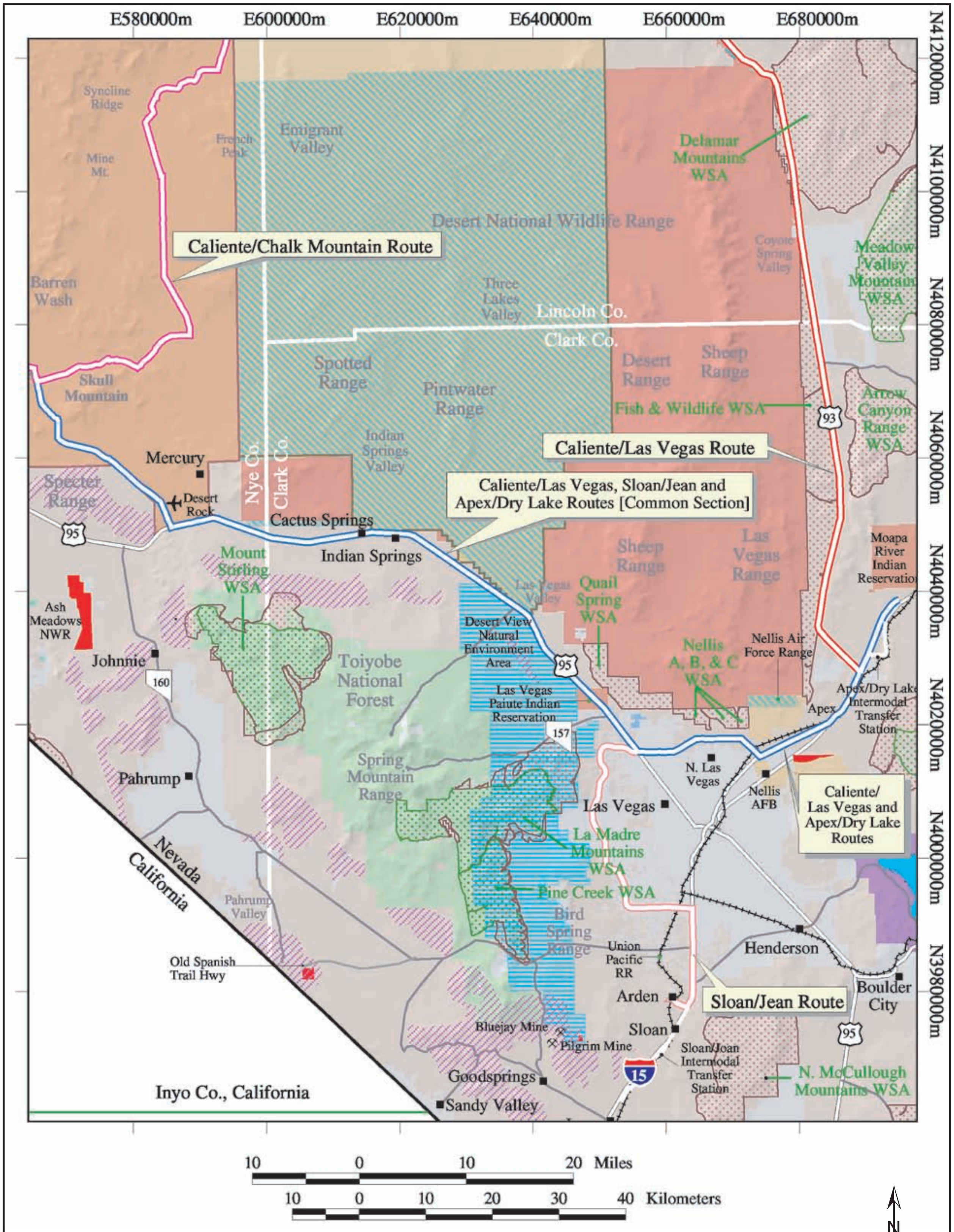


Figure S-30. Candidate heavy-haul truck routes (Index).



Note: See Figure S-35 for legend.

Figure S-31. Candidate heavy-haul truck routes (Map One).



Note: See Figure S-35 for legend.

Figure S-32. Candidate heavy-haul truck routes (Map Two).

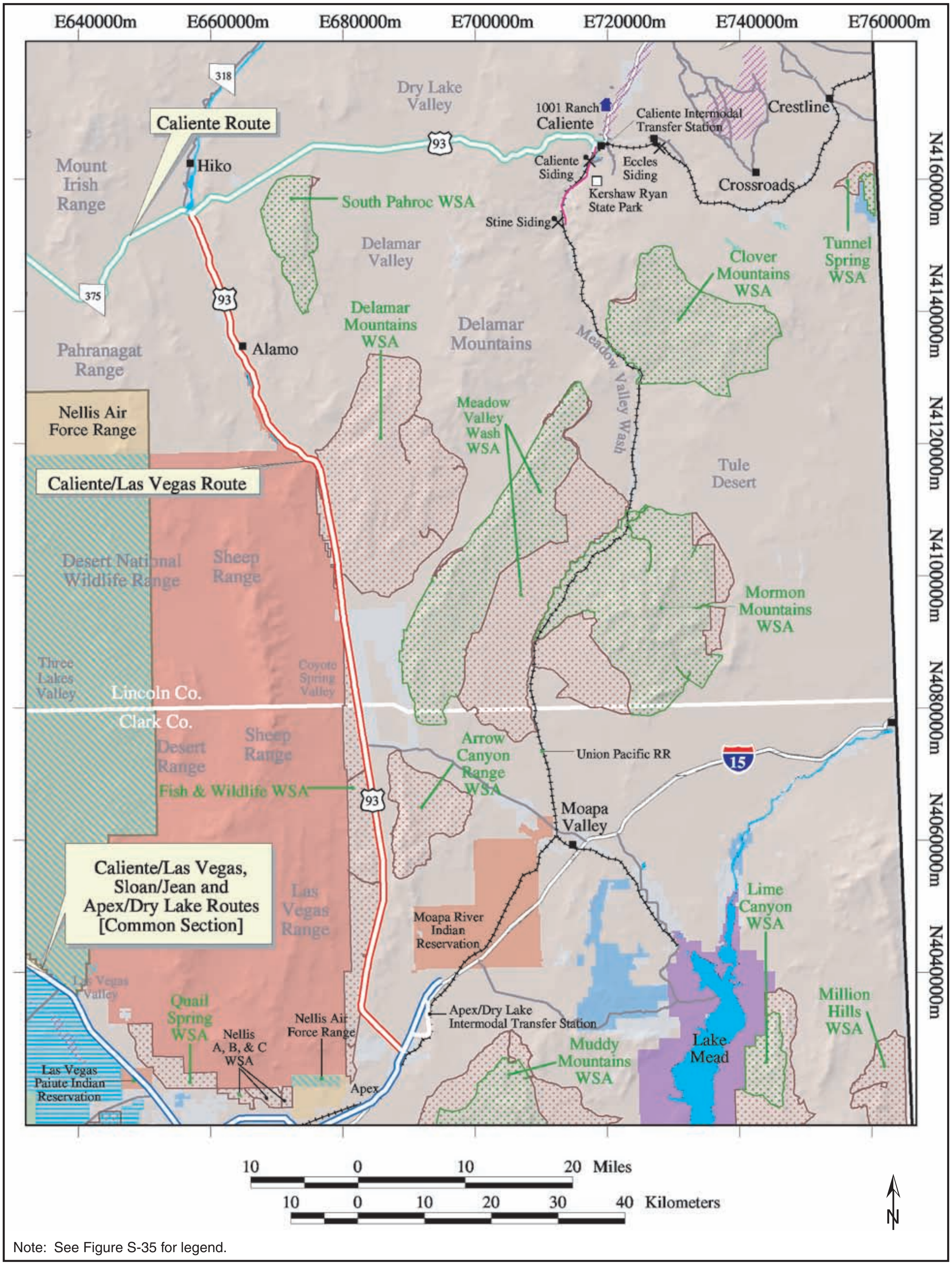


Figure S-33. Candidate heavy-haul truck routes (Map Three).

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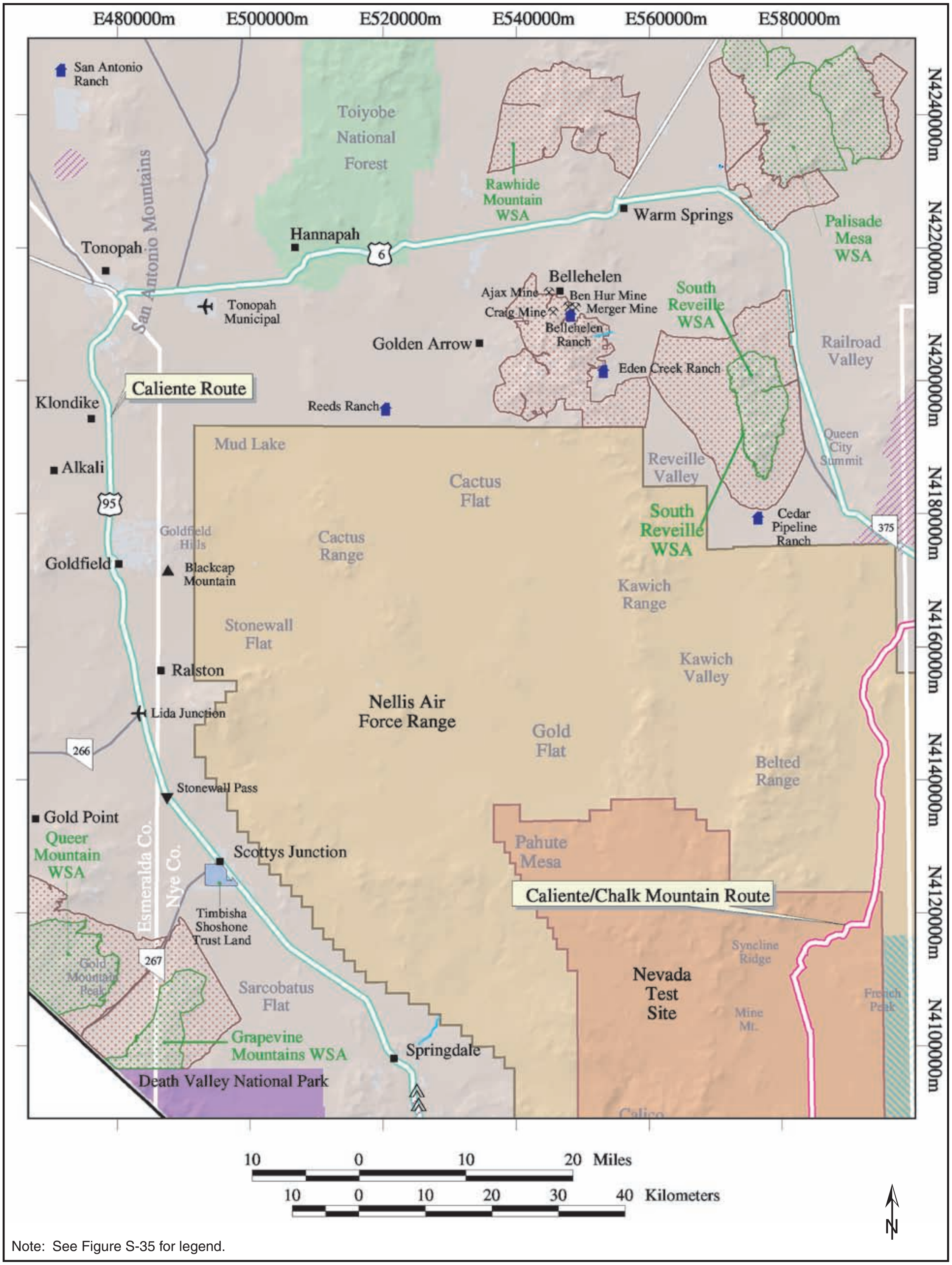

Figure S-34. Candidate heavy-haul truck routes (Map Four).

Figure S-35. Legend for candidate rail corridors and heavy-haul truck routes.

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CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor
exa-	E	1,000,000,000,000,000,000 = 10^{18}
peta-	P	1,000,000,000,000,000 = 10^{15}
tera-	T	1,000,000,000,000 = 10^{12}
giga-	G	1,000,000,000 = 10^{9}
mega-	M	1,000,000 = 10^{6}
kilo-	k	1,000 = 10^{3}
deca-	D	10 = 10^{1}
deci-	d	0.1 = 10^{-1}
centi-	c	0.01 = 10^{-2}
milli-	m	0.001 = 10^{-3}
micro-	µ	0.000 001 = 10^{-6}
nano-	n	0.000 000 001 = 10^{-9}
pico-	p	0.000 000 000 001 = 10^{-12}

Final

Environmental Impact Statement

for a

Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Volume I - Impact Analyses
Chapters 1 through 15

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250

February 2002

Printed on recycled paper with soy ink.

ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the U.S. Department of Energy (DOE) limited the use of acronyms and abbreviations in this environmental impact statement. In addition, acronyms and abbreviations are defined the first time they are used in each chapter or appendix. The acronyms and abbreviations used in the text of this document are listed below. Acronyms and abbreviations used in tables and figures because of space limitations are listed in footnotes to the tables and figures.

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
LCF	latent cancer fatality
MTHM	metric tons of heavy metal
NEPA	National Environmental Policy Act, as amended
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act, as amended
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
REMI	Regional Economic Models, Inc.
RMEI	reasonably maximally exposed individual
Stat.	United States Statutes
TSPA	Total System Performance Assessment
U.S.C.	United States Code

UNDERSTANDING SCIENTIFIC NOTATION

DOE has used scientific notation in this EIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number between 1 and 10 and a positive or negative power of 10. Examples include the following:

Positive Powers of 10
$10^1 = 10 \times 1 = 10$
$10^2 = 10 \times 10 = 100$
and so on, therefore,
$10^6 = 1,000,000$ (or 1 million)

Negative Powers of 10
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/100 = 0.01$
and so on, therefore,
$10^{-6} = 0.000001$ (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are three chances in 1,000,000 that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.

COVER SHEET

RESPONSIBLE AGENCY: U.S. Department of Energy (DOE)

TITLE: *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250)

CONTACT: For more information on this Final Environmental Impact Statement (EIS), write or call:

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Yucca Mountain Site Characterization Office
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North Las Vegas, NV 89036-0307
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Information on this EIS is available on the Internet at the Yucca Mountain Project web site at *http://www.ymp.gov* and on the DOE National Environmental Policy Act (NEPA) web site at *http://tis.eh.doe.gov/nepa/*.

For general information on the DOE NEPA process, write or call:

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U.S. Department of Energy
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ABSTRACT: The Proposed Action addressed in this Final EIS is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain in southern Nevada for the disposal of spent nuclear fuel and high-level radioactive waste currently in storage or projected to be generated at 72 commercial and 5 DOE sites across the United States. The EIS evaluates (1) projected impacts on the Yucca Mountain environment of the construction, operation and monitoring, and eventual closure of the geologic repository; (2) the potential long-term impacts of repository disposal of spent nuclear fuel and high-level radioactive waste; (3) the potential impacts of transporting these materials nationally and in the State of Nevada; and (4) the potential impacts of not proceeding with the Proposed Action. The preferred alternative is to proceed with the Proposed Action and to use mostly rail, both nationally and in Nevada, to transport spent nuclear fuel and high-level radioactive waste.

PUBLIC COMMENTS: In preparing this EIS, DOE considered comments received by letter, electronic mail, facsimile transmission, and oral and written comments given at public hearings at 21 locations across the United States on the Draft EIS, and at 3 locations in Nevada for the Supplement to the Draft EIS.

FOREWORD

The purpose of this environmental impact statement (EIS) is to provide information on potential environmental impacts that could result from a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at the Yucca Mountain site in Nye County, Nevada. The EIS also provides information on potential environmental impacts from an alternative referred to as the No-Action Alternative, under which there would be no development of a geologic repository at Yucca Mountain.

U.S. Department of Energy Actions

The Nuclear Waste Policy Act, enacted by Congress in 1982 and subsequently amended, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.

- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the Nuclear Waste Policy Act, as amended in 1987 (the EIS refers to the amended Act as the NWPA), requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, accompany the recommendation. The Department of Energy (DOE) has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS, in making a decision on whether to recommend the site to the President.

The NWPA requires DOE to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, and after considering other information, the Secretary decided to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after any such notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

Presidential Recommendation and Congressional Action

If, after a recommendation by the Secretary, the President considered the site qualified for application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may object to the recommendation of the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submits such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature submits such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

Actions To Be Taken after Site Designation

If a site designation became effective, the NWPA provides that the Secretary of Energy shall submit to the Nuclear Regulatory Commission an application for a construction authorization for a repository no later than 90 days after the date on which the recommendation of the site designation becomes effective. The NWPA requires the Nuclear Regulatory Commission to adopt DOE's Final EIS to the extent practicable as part of the Nuclear Regulatory Commission's decisionmaking on the License Application.

Decisions Related to Potential Environmental Impacts Considered in the EIS

This EIS analyzes a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a No-Action Alternative, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a basis for comparison with the Proposed Action.

As part of the Proposed Action, which DOE has identified as its preferred alternative, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation nationally and in Nevada, as well as impacts in Nevada of alternative intermodal (rail-to-truck) transfer stations, associated routes for heavy-haul trucks, and alternative corridors for a branch rail line.

DOE believes that the EIS provides the environmental impact information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada. At this time, however, the Department has not identified a preference among the five potential rail corridors in Nevada.

If the Yucca Mountain site was approved (designated), DOE would issue at some future date a Record of Decision to select a mode of transportation. If, for example, mostly rail was selected (both nationally and in Nevada), DOE would then identify a preference for one of the rail corridors in consultation with affected stakeholders, particularly the State of Nevada. In this example, DOE would announce a preferred corridor in the *Federal Register* and other media. No sooner than 30 days after the announcement of a preference, DOE would publish its selection of a rail corridor in a Record of Decision. A similar process would occur in the event that DOE selected heavy-haul truck as its mode of transportation in the State of Nevada. Other transportation decisions, such as the selection of a specific rail alignment within a corridor, would require additional field surveys, State and local government and Native American tribal consultations, environmental and engineering analyses, and appropriate National Environmental Policy Act reviews.

CONTENTS

(NOTE: Each chapter and appendix contains a complete table of contents.)

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1

Purpose and Need for Agency Action

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1. PURPOSE AND NEED FOR AGENCY ACTION

Spent nuclear fuel and *high-level radioactive waste* are long-lived, highly *radioactive* materials that result from nuclear activities. For more than 50 years these materials have accumulated and continue to accumulate at sites across the United States. Because of their nature, spent nuclear fuel and high-level radioactive waste must be isolated, confined, and monitored for long periods. The United States has focused a national effort on siting and developing a *geologic repository* for *disposal* of these materials and on developing systems for transporting the materials from their present *storage* locations to a repository. Figure 1-1 shows 72 commercial nuclear power sites and 5 U.S. Department of Energy (DOE, or the Department) sites in 35 states that currently store these radioactive materials and would ship materials to a repository.

Congress has determined through the passage of the *Nuclear Waste Policy Act,* as amended (NWPA) (42 U.S.C. 10101 *et seq.*), that:

- The Federal Government has the responsibility to dispose of these materials permanently to protect the public health and safety and the *environment*.
- The Federal Government needs to take precautions to ensure these materials do not adversely affect the public health and safety and the environment for this or future generations.
- The *Yucca Mountain site* in southern Nevada should be evaluated as a potential location for a monitored geologic repository.

A geologic repository for spent nuclear fuel and high-level radioactive waste is a system for permanently isolating radioactive materials in a deep *subsurface* location to ensure minimal *risk* to the health and safety of the public. This *environmental impact statement (EIS)* addresses actions that DOE proposes to take to develop a repository at Yucca Mountain, and also considers systems for the transportation of spent nuclear fuel and high-level radioactive waste from the 77 sites to the Yucca Mountain site.

ENVIRONMENTAL IMPACT STATEMENT

An *environmental impact statement* or *EIS* is a detailed analysis that describes the potential beneficial and adverse environmental effects of the proposed action and alternatives.

In addition, DOE has ultimate management responsibility for other highly radioactive materials. Examples of such materials include Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. The Department might need to dispose of these materials in a *monitored geologic repository* to protect public health and safety. However, disposal of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes at the proposed Yucca Mountain Repository could require additional legislative action or a determination by the U.S. Nuclear Regulatory Commission to classify them as high-level radioactive waste.

Section 1.1 describes potential actions and decisions concerning the proposed repository. Section 1.2 provides an overview of spent nuclear fuel and high-level radioactive waste. Section 1.3 describes the major steps in the process Congress has established for evaluations and decisions concerning the Yucca Mountain site. Section 1.4 provides an overview of the site, potential transportation systems for moving spent nuclear fuel and high-level radioactive waste to the site, and studies of the site. Section 1.5 presents information on the EIS process as it applies to the proposal for a monitored geologic repository at Yucca Mountain.

Figure 1-1. Locations of commercial and DOE sites and Yucca Mountain.

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1.1 Potential Actions and Decisions Regarding the Proposed Repository

This EIS analyzes a *Proposed Action* to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a *No-Action Alternative,* under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a basis for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the NWPA, in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

PROPOSED REPOSITORY

DOE has used the term *proposed repository* as a convenience to indicate the relationship of a Yucca Mountain Repository to the Proposed Action of this EIS. DOE could not pursue the use of Yucca Mountain for a repository unless the Secretary of Energy decided to recommend approval of the site to the President and a Presidential site designation became effective. At that time, DOE would submit a License Application to the Nuclear Regulatory Commission seeking authorization to construct a repository at Yucca Mountain.

As part of the Proposed Action, which DOE has identified as its preferred *alternative,* the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the impacts of rail and truck transportation nationally and in Nevada, as well as impacts in Nevada of alternative corridors for a branch rail line, routes for heavy-haul trucks, and alternative and associated *intermodal (rail-to-truck) transfer stations*.

DOE believes that the EIS provides the environmental *impact* information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or *heavy-haul truck* with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada. At this time, the Department has not identified a preference among the five potential rail corridors in Nevada.

If the Yucca Mountain site was approved, DOE would issue at some future date a Record of Decision to select a mode of transportation. If, for example, mostly rail was selected (both nationally and in Nevada), DOE would then identify a preference for one of the rail *corridors* in consultation with affected *stakeholders,* particularly the State of Nevada. In the example, DOE would announce a preferred corridor in the *Federal Register* and other media. No sooner than 30 days after the announcement of a preference, DOE would publish its selection of a rail corridor in a *Record of Decision*. A similar process would occur in the event that DOE selected heavy-haul truck as its mode of transportation in the State of Nevada. Other transportation decisions, such as the selection of a specific rail *alignment* within a corridor, would require additional field surveys, State and local government and Native American tribal consultations, environmental and engineering analyses, and *National Environmental Policy Act* reviews.

1.2 Radioactive Materials Considered for Disposal in a Monitored Geologic Repository

Commercial nuclear powerplants, which supply approximately 20 percent of the Nation's electricity, produce spent nuclear fuel. In addition, DOE manages a complex of large government-owned facilities that formerly produced nuclear weapons materials, and in doing so produced spent nuclear fuel and high-level radioactive waste. DOE also operates research reactors that produce spent nuclear fuel and processing facilities that produce high-level radioactive waste.

The following discussion describes spent nuclear fuel and high-level radioactive waste, including *mixed-oxide fuel* (a mixture of uranium oxide and plutonium oxide that could be used to power commercial nuclear reactors) and immobilized plutonium forms. The discussion also identifies other waste forms, particularly Greater-Than-Class-C wastes and Special-Performance-Assessment-Required wastes, that are currently classified as *low-level radioactive* wastes but that could require disposal in a monitored geologic repository.

1.2.1 GENERATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

The material used to power commercial nuclear reactors typically consists of cylindrical fuel pellets made of uranium oxide. Fuel pellets are placed in tubes that are ordinarily about 3.7 meters (12 feet) long and 0.64 centimeter (0.25 inch) in diameter. Sealed tubes with fuel pellets inside them are called fuel rods (Appendix A). Fuel rods are arranged in bundles called fuel assemblies (see Figure 1-2), which are placed in a *reactor*.

In the reactor, neutrons from the fuel strike other uranium atoms, causing them to split into parts, and producing heat, radioactive *fission products,* and more free neutrons. This splitting of atoms is a form of nuclear reaction called *fission*. The neutrons produced by the fission process sustain the nuclear reaction by striking other uranium atoms in the fuel pellets, causing additional atoms to split. Control of the configuration and machinery associated with the fuel assemblies provides control of the rate at which fission occurs and, consequently, the amount of heat produced.

In a commercial power reactor, the heat that fission produces is used to convert water to steam. The steam turns turbine generators to produce electric energy. The reactors that power many naval vessels use the steam primarily to turn turbines to provide ship propulsion. Some research reactors also use the steam produced to generate electricity.

After a period in operation, enough of the fissile uranium atoms have undergone fission that the fuel is said to be "spent"; some of these spent nuclear fuel assemblies must be replaced with fresh fuel for operation to continue. During replacement, fresh fuel is placed in the reactor and spent fuel is placed in a pool of water. In commercial reactors, typical fuel cycles run 18 to 24 months, after which 25 to 50 percent of the spent nuclear fuel is replaced.

Nuclear reactor operators initially store spent nuclear fuel under water in spent fuel pools because of high levels of *radioactivity* and heat from *decay* of radionuclides. When the fuel has cooled and decayed sufficiently, operators can use two storage options: (1) continued in-pool storage or (2) above-ground *dry storage* in an independent installation. Thirty-three sites have existing or planned independent above-ground dry storage facilities. Dry storage includes the storage of spent nuclear fuel at reactor sites in approved storage casks.

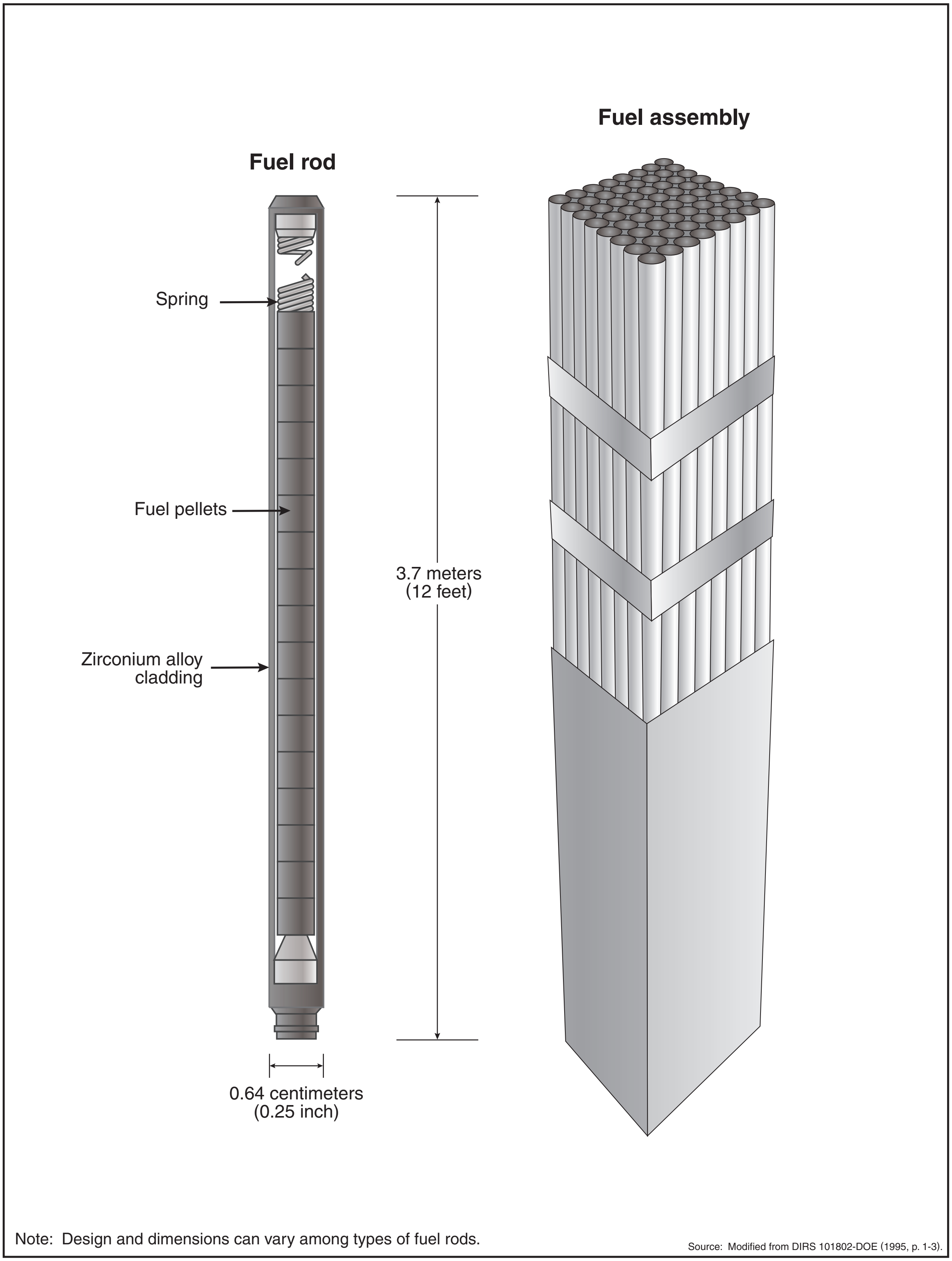


Figure 1-2. Typical commercial nuclear fuel assembly and rod.

Beginning in 1944, the United States operated reactors to produce materials such as plutonium for nuclear weapons. All of these reactors have been shut down for several years. When defense plutonium production reactors were operating, they used a controlled fission process to irradiate nuclear fuel and generate plutonium. DOE used chemical processes (called *reprocessing*) to extract plutonium and other materials from spent nuclear fuel for defense purposes. One of the chemical byproducts remaining after reprocessing is high-level radioactive waste. The reprocessing of limited quantities of naval reactor fuels and some commercial reactor fuels, DOE test reactor fuels, and university research reactor fuels has also produced high-level radioactive waste.

Concerns about safety and environmental hazards contributed to DOE decisions to shut down parts of the weapons production complex in the 1980s. The shutdown, which became permanent due primarily to the reduced need for weapons materials at the end of the Cold War, included both production reactors and spent fuel reprocessing facilities. As a result, not all *DOE spent nuclear fuel* was reprocessed. Some of this fuel is now stored at DOE sites.

1.2.2 SPENT NUCLEAR FUEL

Spent nuclear fuel consists of nuclear fuel that has been withdrawn from a nuclear reactor following *irradiation,* provided that the constituent elements of the fuel have not been separated by reprocessing. *Commercial spent nuclear fuel* comes from nuclear reactors operated to produce electric power for domestic use. DOE manages spent nuclear fuel from DOE defense production reactors, U.S. naval reactors, and DOE test and experimental reactors, as well as fuel from university research reactors, commercial reactor fuel acquired by DOE for research and development, and fuel from foreign research reactors. Most nuclear fuel is encased in highly *corrosion-resistant cladding* before being placed in a reactor. The fuel remains in the cladding after it is irradiated and withdrawn as spent nuclear fuel. The purpose of the cladding is to protect the fuel in operating conditions associated with a reactor. Cladding, if it is not damaged or corroded, has the capability to isolate the spent nuclear fuel and delay the release of radionuclides to the environment for long periods.

Spent nuclear fuel is intensely radioactive in comparison to nonirradiated fuel and would be the primary source of radioactivity and heat generation in the proposed repository.

1.2.2.1 Commercial Spent Nuclear Fuel

Commercial spent nuclear fuel typically consists of uranium oxide fuel (which also contains actinides, fission products, and other materials), the cladding that contains the fuel, and the *assembly* hardware. The cladding for nuclear fuel assemblies is normally made of a *zirconium* alloy. However, about 1 percent of the spent nuclear fuel included in the Proposed Action is clad in stainless steel (Appendix A).

The sources of commercial spent nuclear fuel are the commercial nuclear powerplants throughout the United States. Figure 1-1 shows the locations of these sites. Appendix A, Section A.2.1, provides details on spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site.

Mixed-oxide fuel would be part of the commercial spent nuclear fuel inventory for the proposed repository. Section 1.2.4 includes a discussion of mixed-oxide fuel.

1.2.2.2 DOE Spent Nuclear Fuel

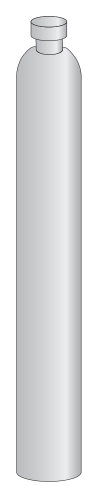
DOE spent nuclear fuel, like commercial spent nuclear fuel, has been withdrawn from a reactor following irradiation. Much of the DOE spent nuclear fuel is associated with past operations of reactors at the Hanford and Savannah River Sites that previously produced material for DOE's defense programs and research and development programs. These reactors are no longer operating. Smaller quantities of spent nuclear fuel have resulted from experimental reactor operations and from research conducted by approximately 55 university- and government-owned test reactors (see Appendix A). DOE spent nuclear fuel also includes spent fuel from reactors on nuclear-powered naval vessels and naval reactor prototypes.

DOE stores most of its spent nuclear fuel in pools or dry storage facilities at three primary locations: the Hanford Site in Washington State, the Idaho National Engineering and Environmental Laboratory in Idaho, and the Savannah River Site in South Carolina. Some DOE spent nuclear fuel is currently stored at the Fort St. Vrain dry storage facility in Colorado (see Figure 1-1). Additional small quantities remain at other locations. With the exception of Fort St. Vrain, which will retain its spent nuclear fuel in dry storage until disposition, DOE plans to ship all of the spent nuclear fuel for which it is responsible from other sites to one of the three primary locations mentioned above for storage and preparation for ultimate disposition [discussed in DIRS 103205-DOE (1995, all)]. This EIS does not analyze consolidation of spent nuclear fuel at DOE sites (see DIRS 101802-DOE 1995, all). Appendix A, Section A.2.2, provides details on DOE spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site.

1.2.3 HIGH-LEVEL RADIOACTIVE WASTE

DOE stores high-level radioactive waste in below-grade tanks at the Hanford Site, the Savannah River Site, the Idaho National Engineering and Environmental Laboratory, and the West Valley Demonstration Project in New York, a site presently owned by the New York State Energy Research and Development Authority (see Figure 1-1 for locations). High-level radioactive waste can be in a liquid, sludge, or saltcake form, and a solid immobilized glass form (see below). Liquid waste consists of water and organic compounds that contain dissolved salts. Sludge is a mixture of insoluble (that is, materials that will not dissolve in tank liquid) metallic salt compounds that precipitated and settled out of the solution after the waste became alkaline. Saltcake is primarily sodium and aluminum salt that crystallized from the solution following evaporation. High-level radioactive waste can also include other highly radioactive material that the Nuclear Regulatory Commission determines by rule to require permanent *isolation* (Nuclear Waste Policy Act definitions, Section 12), as well as immobilized plutonium waste forms. Appendix A, Section A.2.3, provides details on high-level radioactive waste and discusses the amount currently stored and projected to be stored at each site. Included in this total is immobilized high-level radioactive waste that will result from the electrometallurgical treatment of DOE sodium-bonded nuclear fuel at Argonne National Laboratory-West on the Idaho National Engineering and Environmental Laboratory site [*Record of Decision for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (65 *FR* 56565; September 19, 2000)].

The DOE process for preparing high-level radioactive waste for disposal starts with the transfer of the waste from storage tanks to a treatment facility. Treatment ordinarily includes separation of the waste into high-activity and low-activity fractions, followed by *vitrification* of the high-activity fraction. Vitrification involves adding materials to the waste and heating the mixture until it melts. The melted mixture is poured into canisters, where it cools into a solid glass or ceramic form that is very resistant to the leaching of radionuclides. The solidified, immobilized glass forms have been developed to keep the waste stable, confined, and isolated from the environment when inserted into disposal containers and disposed of in a monitored geologic repository. DOE will store the solidified high-level radioactive waste on the sites in *canisters* before eventual *shipment* to a repository. Figure 1-3 shows a representative vitrified high-level radioactive waste canister.



Note: There are two canister lengths - 120 inches and 180 inches.

Figure 1-3. Vitrified high-level radioactive waste canister.

The low-activity fraction does not meet the definition of high-level radioactive waste. It is classified as low-level waste and is therefore considered generally acceptable for near-surface disposal under separate low-level waste disposal regulations.

DOE has begun to solidify and immobilize waste at the Savannah River Site, has completed most solidification and immobilization at West Valley, and plans to begin solidification and immobilization at Hanford. DOE has prepared a Draft EIS (DIRS 155100-DOE 1999, all) to help it determine the method it will use to prepare high-level radioactive waste at the Idaho National Engineering and Environmental Laboratory for disposal.

1.2.4 SURPLUS WEAPONS-USABLE PLUTONIUM

DOE has declared some weapons-usable plutonium to be surplus to national security needs (DIRS 118979-DOE 1999, p. 1-1). This material includes purified plutonium, nuclear weapons components, and materials and residues that could be processed to produce purified plutonium (Appendix A, Section A.2.4). DOE currently stores these plutonium-containing materials at various sites throughout the United States.

DOE could emplace surplus weapons-usable plutonium in the repository in two forms. One form would be an immobilized plutonium ceramic that DOE would dispose of as high-level radioactive waste. The second form would be mixed uranium and plutonium oxide fuel (called mixed-oxide fuel) assemblies that would be used for power production in commercial nuclear reactors and disposed of in the same manner as other commercial spent nuclear fuel. The analysis in this EIS assumed that approximately one-third of the surplus plutonium would be immobilized and approximately two-thirds would be mixed-oxide spent nuclear fuel (Appendix A). The actual split could include the immobilization of between one-third and all of the plutonium. Appendix A, Section A.2.4, contains details on sources, generation and storage status, and material characteristics of this surplus plutonium.

1.2.5 OTHER WASTE TYPES WITH HIGH RADIONUCLIDE CONTENT

The Nuclear Regulatory Commission classifies most low-level radioactive waste into Classes A, B, and C (10 CFR Part 61), which reflect increasing levels of radioactivity. *Greater-Than-Class-C* is the term for radioactive waste generated by commercial activities that exceeds Nuclear Regulatory Commission concentration limits for Class C waste, as specified in 10 CFR Part 61. The Nuclear Regulatory Commission has determined that shallow land burial of Greater-Than-Class-C low-level radioactive waste generally is not acceptable. *Special-Performance-Assessment-Required* waste is DOE-generated low-level radioactive waste with radioactive content higher than Class C shallow land disposal limits.

1.3 National Effort To Manage Spent Nuclear Fuel and High-Level Radioactive Waste

This section provides background information on the management of spent nuclear fuel and high-level radioactive waste, and describes the Nuclear Waste Policy Act of 1982 and its amendments.

1.3.1 BACKGROUND

In the late 1950s, active investigation began on the concept of mined geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste. In the 1970s, the United States reprocessed a small amount of commercial spent nuclear fuel to extract plutonium and studied the feasibility of expanded reprocessing. The plutonium would have been combined with uranium and used again as reactor fuel, substantially reducing the total amount of new enriched uranium required (DIRS 103414-NRC 1976, all). President Carter cancelled consideration of this approach, leaving disposal as the primary option for spent nuclear fuel.

In a February 12, 1980, message to Congress, President Carter stated that the safe disposal of radioactive materials generated by both defense and civilian nuclear activities is a national responsibility. In fulfillment of that responsibility, he announced a comprehensive program for the management of radioactive materials and adopted an interim planning strategy focusing on "the use of mined geologic repositories capable of accepting both waste from reprocessing and unreprocessed commercial spent fuel" (DIRS 104832-DOE 1980, p. 2.7). President Carter stated that he would reexamine this interim strategy and decide if changes were required after the completion of the environmental reviews required by the National Environmental Policy Act. As part of this reexamination, DOE issued the *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DIRS 104832-DOE 1980, all). That EIS analyzed the environmental impacts that could occur if DOE developed and implemented various technologies for the management and disposal of spent nuclear fuel and high-level radioactive waste. It examined several alternatives, including mined geologic disposal, very deep hole disposal, disposal in a mined cavity that resulted from rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal, and no action. The 1981 Record of Decision for that EIS announced the DOE decision to pursue the mined geologic disposal alternative for the disposition of spent nuclear fuel and high-level radioactive waste (46 *FR* 26677; May 14, 1981).

Internationally, permanent geologic disposal is the consensus choice of technology for the management of commercial spent nuclear fuel. The United States remains committed to disposal of commercial and DOE spent nuclear fuel, DOE high-level radioactive waste, and surplus weapons-usable plutonium in a geologic repository. This commitment assumes the acceptance and disposal in a U.S. repository of certain spent nuclear fuel that contains uranium enriched in the United States that has been used in foreign research reactors. This approach supports the U.S. advocacy for limiting international trade in weapons-usable nuclear materials and signals the U.S. commitment to a policy of nonproliferation of nuclear materials.

1.3.2 NUCLEAR WASTE POLICY ACT

In 1983, Congress enacted the Nuclear Waste Policy Act (Public Law 97-425; 96 Stat. 2201), which acknowledged the Federal Government's responsibility to provide permanent disposal of the nation's spent nuclear fuel and high-level radioactive waste, and established the Office of Civilian Radioactive Waste Management, which has the responsibility to carry out the evaluative, regulatory, developmental, and operational activities the Act assigns to the Secretary of Energy. The Nuclear Waste Policy Act began a process for selecting sites for technical study as potential geologic repository locations. In accordance with this process (shown in Figure 1-4), DOE identified nine candidate sites, the Secretary of Energy nominated five of the nine sites for further consideration, and DOE issued environmental assessments for the five sites in May 1986. DOE recommended three of the five sites (Deaf Smith County, the Hanford Site, and Yucca Mountain) for possible study as repository site candidates, and President Reagan approved the three as candidates. In addition, the Nuclear Waste Policy Act recognized a need to ensure that spent nuclear fuel and high-level radioactive waste now accumulating at commercial and DOE sites do not adversely affect public health and safety and the environment [NWPA, Section 111(a)(7)].

In 1987, Congress significantly amended the Nuclear Waste Policy Act. This Act, as amended (42 U.S.C. 10101 *et seq.*), which this EIS refers to as the NWPA, identified one of the three Presidentially approved candidate sites, Yucca Mountain, as the only site to be studied as a potential location for a geologic repository. Congress directed the Secretary of Energy to study the Yucca Mountain site and recommend whether the President should approve the site for development as a repository. Congress also required that a Final EIS accompany any Secretarial recommendation to approve the Yucca Mountain site to the President [NWPA, Section 114(a)(1)]. DOE has prepared this EIS to fulfill that requirement.

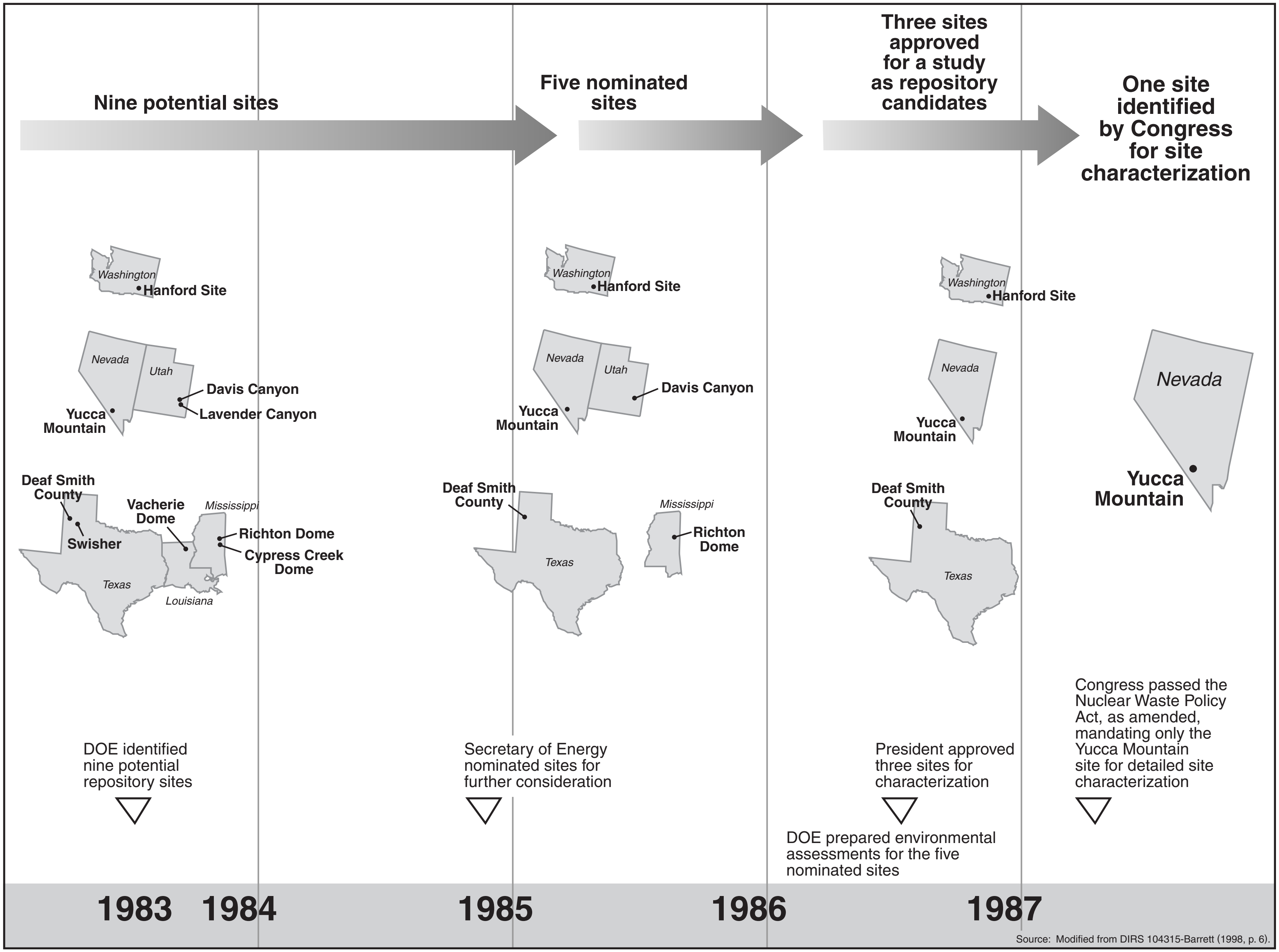


Figure 1-4. Events leading to selection of Yucca Mountain for study.

1.3.2.1 Requirement To Study and Evaluate the Site

In addition to the general responsibilities it establishes, the NWPA requires the Secretary of Energy specifically to characterize and evaluate the Yucca Mountain site for a geologic repository. The Act directs the Secretary of Energy to characterize only the Yucca Mountain site as a potential repository location and establishes a decisionmaking process to determine whether to designate Yucca Mountain as qualified for an application for repository construction authorization (NWPA, Sections 113, 114, 115, and 160).

Congress created the *Nuclear Waste Technical Review Board* as an independent organization to evaluate the technical and scientific validity of *site characterization* activities for the proposed repository and activities related to the packaging and transportation of spent nuclear fuel and high-level radioactive waste (NWPA, Section 503). The Nuclear Waste Technical Review Board must report findings, conclusions, and recommendations based on its evaluations to Congress and to the Secretary of Energy at least twice each year (NWPA, Section 508).

1.3.2.2 Elements of Site Evaluation

Sections 113, 114, and 115 of the NWPA contain specific and mostly sequential steps in the evaluation and decisionmaking process Congress has established for the Yucca Mountain site. The rest of this section and Section 1.3.2.3 describe that process.

The first steps in the evaluation and decisionmaking process for the Yucca Mountain site require the Secretary of Energy and, by extension, DOE, to gather data about Yucca Mountain and evaluate whether to recommend Yucca Mountain for approval as the site for a *license application* to the Nuclear Regulatory Commission for repository development. The Secretary's specific duties include:

- Undertake physical characterization of the Yucca Mountain site.
- Hold public hearings in the Yucca Mountain site *vicinity*.
- Prepare a description of the site, of spent nuclear fuel and high-level radioactive waste forms and packaging to be used, and of site safety.
- Decide whether to make a recommendation to the President on approval of the site for development as a repository.

Section 1.4.3.7 describes the elements that the Secretary of Energy must develop and consider in making a *site recommendation* to the President and in providing a statement of the basis for that recommendation.

The NWPA directs the Secretary of Energy to evaluate a *scenario* under which DOE would place an inventory of material in the proposed Yucca Mountain Repository. This EIS considers a repository inventory of 70,000 *metric tons of heavy metal (MTHM)* comprised of 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM of DOE spent nuclear fuel and high-level radioactive waste. This overall inventory includes surplus weapons-usable plutonium as spent mixed-oxide fuel and immobilized plutonium. Appendix A provides additional details of the inventory of materials.

Operating nuclear powerplants could generate approximately 105,000 MTHM of spent nuclear fuel through 2046. The total projected DOE inventory of materials includes 2,500 MTHM of spent nuclear fuel and approximately 22,280 canisters of high-level radioactive waste. Chapter 8 evaluates potential consequences of using a repository at Yucca Mountain to dispose of all spent nuclear fuel and high-level radioactive waste that could be produced through 2046 for which DOE retains ultimate responsibility.

1.3.2.3 Site Qualification and Authorization Process

1.3.2.3.1 *U.S. Department of Energy Actions*

The Nuclear Waste Policy Act of 1982, subsequently amended, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the Nuclear Waste Policy Act, as amended in 1987 (the EIS refers to the amended Act as the NWPA), requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, would accompany the recommendation. DOE has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS, in making a decision on whether to recommend the site to the President.

The NWPA requires DOE to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, and after considering other information, the Secretary decided to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after any such notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

1.3.2.3.2 *Presidential Recommendation and Possible State and Congressional Action*

If, after any recommendation by the Secretary, the President considered the site qualified for an application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may disapprove the site designation by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submit such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature submitted such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

1.3.2.3.3 *Actions After Site Designation*

If a site designation became effective, the NWPA provides that the Secretary of Energy shall submit to the Nuclear Regulatory Commission an application for a construction authorization for a repository no later than 90 days after the date on which the site designation becomes effective. The NWPA requires the Commission to adopt DOE's Final EIS to the extent practicable as part of the Commission's decisionmaking on the License Application.

1.3.2.4 Environmental Protection and Approval Standards for the Yucca Mountain Site

Section 121 of the Nuclear Waste Policy Act of 1982 directed the U.S. Environmental Protection Agency to establish generally applicable standards to protect the general environment from *offsite* releases from radioactive materials in repositories and directed the Nuclear Regulatory Commission to issue technical requirements and criteria for such repositories. In 1992, Congress modified the rulemaking authorities of the Environmental Protection Agency and the Nuclear Regulatory Commission in relation to a possible repository at Yucca Mountain. Section 801(a) of the Energy Policy Act of 1992 directed the Environmental Protection Agency to retain the National Academy of Sciences to conduct a study and issue findings and recommendations on setting reasonable standards for protecting public health and safety in relation to a repository at Yucca Mountain. Section 801(a) also directs the Environmental Protection Agency to establish Yucca Mountain-specific standards based on and consistent with the Academy's findings and recommendations.

The National Academy of Sciences issued its findings and recommendations in a 1995 report (DIRS 100018-National Research Council 1995, all). The Environmental Protection Agency has issued standards for both storage and disposal of radioactive material at Yucca Mountain (40 CFR Part 197). The standards set health-based limits and *groundwater* protection limits for any radioactive releases from a repository at Yucca Mountain.

This EIS includes evaluation of the proposed Yucca Mountain repository's capability to satisfy the Environmental Protection Agency's regulations. Chapter 11 contains a more detailed discussion of these regulations and other requirements.

Section 801(b) of the Energy Policy Act directs the Nuclear Regulatory Commission to revise its general technical requirements and criteria for geologic repositories (10 CFR Part 60) to be consistent with the Environmental Protection Agency site-specific Yucca Mountain standards established at 40 CFR Part 197. The Nuclear Regulatory Commission has issued site-specific technical requirements and criteria (10 CFR Part 63). The Commission would use these requirements and criteria to evaluate an application to construct a repository at Yucca Mountain, to receive and possess spent nuclear fuel and high-level radioactive waste at such a repository, and to close and decommission such a repository.

The Nuclear Waste Policy Act of 1982 required the Secretary of Energy to issue general guidelines for use in recommending potential repository sites for detailed site characterization. DOE issued these guidelines in 1984 (10 CFR Part 960).

DOE has established site-specific regulations (10 CFR Part 963) that provide a portion of the basis for the evaluation of site suitability, as provided in the NWPA. The EIS provides current information on the proposed repository and presents an evaluation of the repository site, potential repository development, and anticipated repository performance measured against human health and other relevant technical criteria. DOE will comply with all applicable environmental and approval standards for the Yucca Mountain site.

1.4 Yucca Mountain Site and Proposed Repository

Spent nuclear fuel and high-level radioactive waste generate large amounts of *radiation* from the gradual decay of radioactive isotopes. These isotopes have the potential to cause severe human health impacts. In addition, the materials can generate heat from *radioactive decay* for periods lasting thousands of years. The Nuclear Waste Policy Act directs DOE to analyze and consider the disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository.

1.4.1 YUCCA MOUNTAIN SITE

The site of the proposed Yucca Mountain Repository (see Figure 1-5) is on lands administered by the Federal Government in a remote area of the Mojave Desert in Nye County in southern Nevada, approximately 160 kilometers (100 miles) northwest of Las Vegas, Nevada. The area surrounding the site is sparsely populated and receives an average of about 170 millimeters (7 inches) of precipitation per year. Chapter 3, Section 3.1, provides detailed information on the environment at the site.

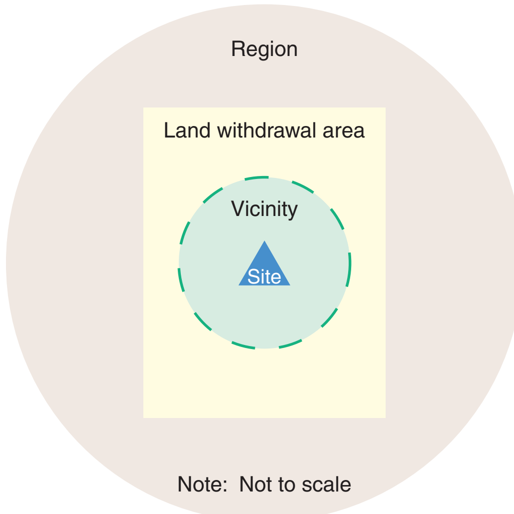
SITE-RELATED TERMS

Yucca Mountain site (the site): The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

Yucca Mountain vicinity: A general term used in nonspecific discussions about the area around the Yucca Mountain site. The EIS also uses terms such as area, proximity, etc., in a general context.

Land withdrawal area: An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

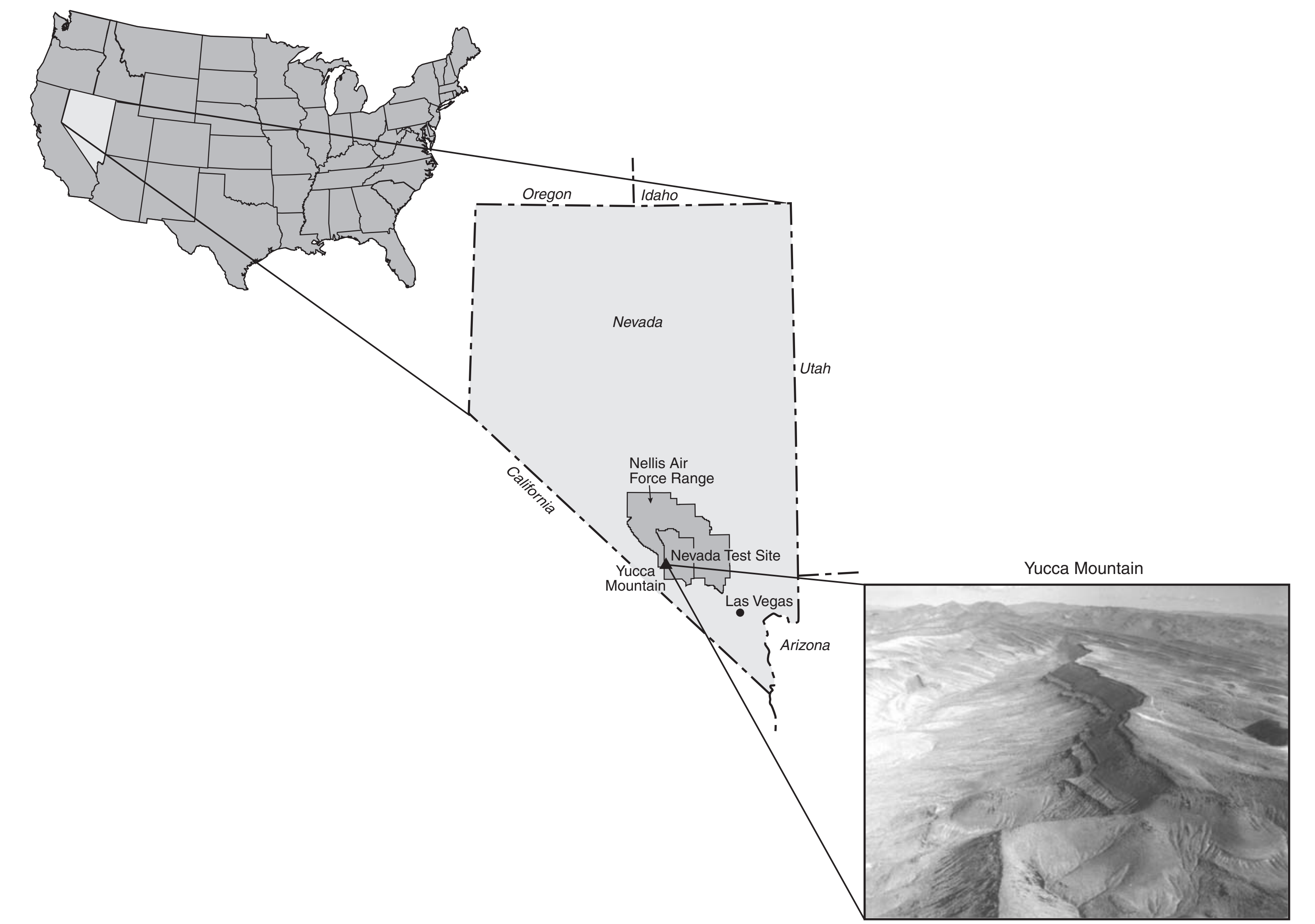
Region of influence (the region): A specialized term indicating a specific area of study for each of the resource areas that DOE assessed for the EIS analyses.



Controlled Area (as defined in 40 CFR Part 197) *(not shown on illustration):* The area surrounding the repository that is restricted to public access for the long term, as identified by passive institutional controls that DOE would install at closure. The controlled area could include as much as 300 square kilometers (about 120 square miles) surface and subsurface area. It would extend no more than 5 kilometers (3 miles) in any direction from the repository footprint except in the predominant direction of groundwater flow, where the controlled area would extend no farther south than 36 degrees, 40 minutes, 13.6661 seconds North latitude, the present latitude of the southwest corner of the Nevada Test Site [about 18 kilometers (11 miles)].

The Yucca Mountain site has several characteristics that would be expected to limit possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste. It is isolated from concentrations of human population and human activity and is likely to remain so. The very *arid* climate results in a relatively small volume of water that can move as groundwater in the mountain's unsaturated zone. The groundwater table sits substantially below the level at which DOE would locate a repository, providing additional separation between water sources and materials emplaced in waste packages. Maximizing the separation of water from the repository would minimize corrosion and would delay any mobilization and transport of radionuclides from the repository, as discussed in Chapter 5.

Groundwater from Yucca Mountain flows into a closed, sparsely populated hydrogeologic basin. A closed basin is one in which water introduced into the basin by rain cannot flow out the basin to any river or ocean. This closed basin provides a *natural barrier* to a general spread of radionuclides in the event that radioactive *contamination* reached the groundwater.



Source: Modified from DIRS 101779-DOE (1998, Overview, pp. 10 and 11).

Figure 1-5. Yucca Mountain location.

The *land withdrawal area* analyzed in the EIS includes about 600 square kilometers (230 square miles or 150,000 acres) of land currently under the control of DOE, the U.S. Department of Defense, and the U.S. Department of the Interior (see Figure 1-6). Approximately as many as 6.0 square kilometers (1,500 acres) comprising the repository site would be needed for development of surface repository facilities, with the remainder serving as a large buffer zone. If Yucca Mountain is recommended and approved for development as a repository, all or a portion of the land withdrawal area would have to be withdrawn permanently from public access to satisfy Nuclear Regulatory Commission licensing requirements at 10 CFR 60.121. If the land to be withdrawn included land that this EIS does not consider for withdrawal, DOE would perform additional analysis as required by the National Environmental Policy Act.

1.4.2 PROPOSED DISPOSAL APPROACH

The proposed monitored geologic repository at Yucca Mountain would be a large underground excavation with a network of *drifts* (tunnels) serving as the *emplacement* area for spent nuclear fuel and high-level radioactive waste. Rail, *legal-weight trucks,* or heavy-haul trucks would provide most of the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to the repository. Barges could move spent nuclear fuel from some sites to rail and truck transfer points. Shippers would transport the materials in Nuclear Regulatory Commission-approved shipping containers designed to transport radioactive materials with minimal risk to the public health and safety and to the environment. (Chapter 6 discusses potential transportation systems.) Figure 1-7 shows the concept of temporary storage of spent nuclear fuel and high-level radioactive waste at storage sites, transporting these materials to the proposed repository, and disposing of the materials in an emplacement area.

At the repository, the material would be loaded in disposal containers. The filled disposal containers would be sealed, thereby becoming waste packages. The waste packages would be moved underground by rail. Remote-controlled handling vehicles would place the waste packages in emplacement drifts. The waste packages, which would be designed to remain intact for thousands of years (at a minimum), would be part of an *engineered barrier system* inside the mountain that would isolate spent nuclear fuel and high-level radioactive waste from the environment. The engineered barrier system, together with the geologic and hydrologic properties of the Yucca Mountain site, would ensure that a potential release of radioactive material after repository *closure* would meet applicable performance standards to contain and isolate the waste for 10,000 years or more. Chapter 5 provides detailed discussions of the *natural system* and of waste packages. Chapter 2 describes the Proposed Action at Yucca Mountain in additional detail, including the transportation activities required to move the spent nuclear fuel and high-level radioactive waste to the site.

Under the NWPA, the proposed repository, if authorized, would be a facility for the permanent disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. The Nuclear Waste Policy Act requires the Nuclear Regulatory Commission to include in the authorization a prohibition against the emplacement of more than 70,000 MTHM in the first repository until a second repository is in operation [Nuclear Waste Policy Act, Section 114(d)]. DOE has allocated 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM equivalent of DOE spent nuclear fuel and high-level radioactive waste to the proposed repository at Yucca Mountain. The Proposed Action that this EIS evaluates, therefore, includes the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to Yucca Mountain and the emplacement of as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the proposed repository. Chapter 8 of this EIS analyzes cumulative impacts from the disposal at Yucca Mountain of all spent nuclear fuel and high-level radioactive waste projected to be produced through 2046 for which DOE will retain ultimate responsibility. Chapter 8 also considers the disposal of *Greater-Than-Class-C waste* and *Special-Performance-Assessment-Required waste* at Yucca Mountain.

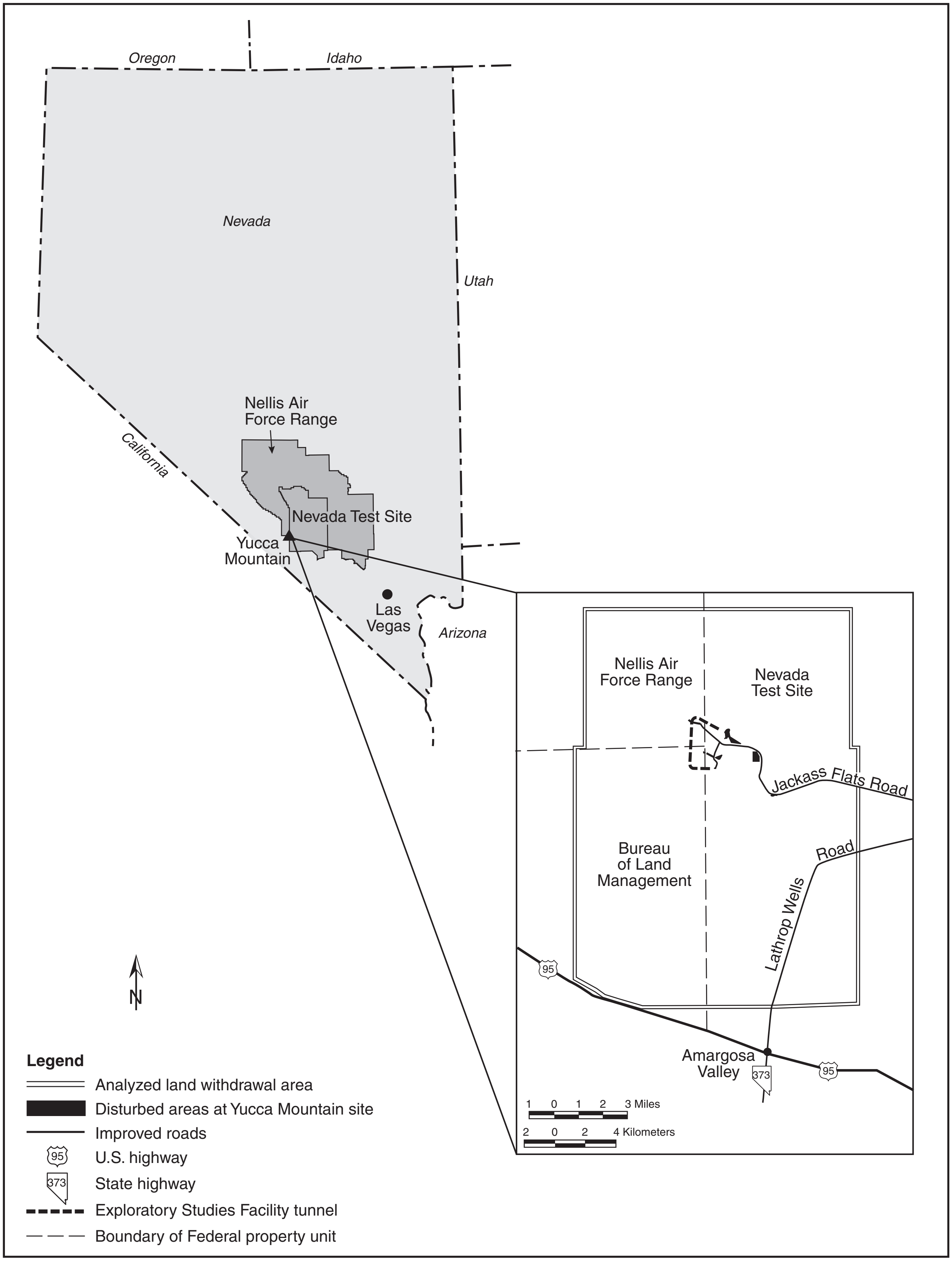


Figure 1-6. Land withdrawal area used for analytical purposes.

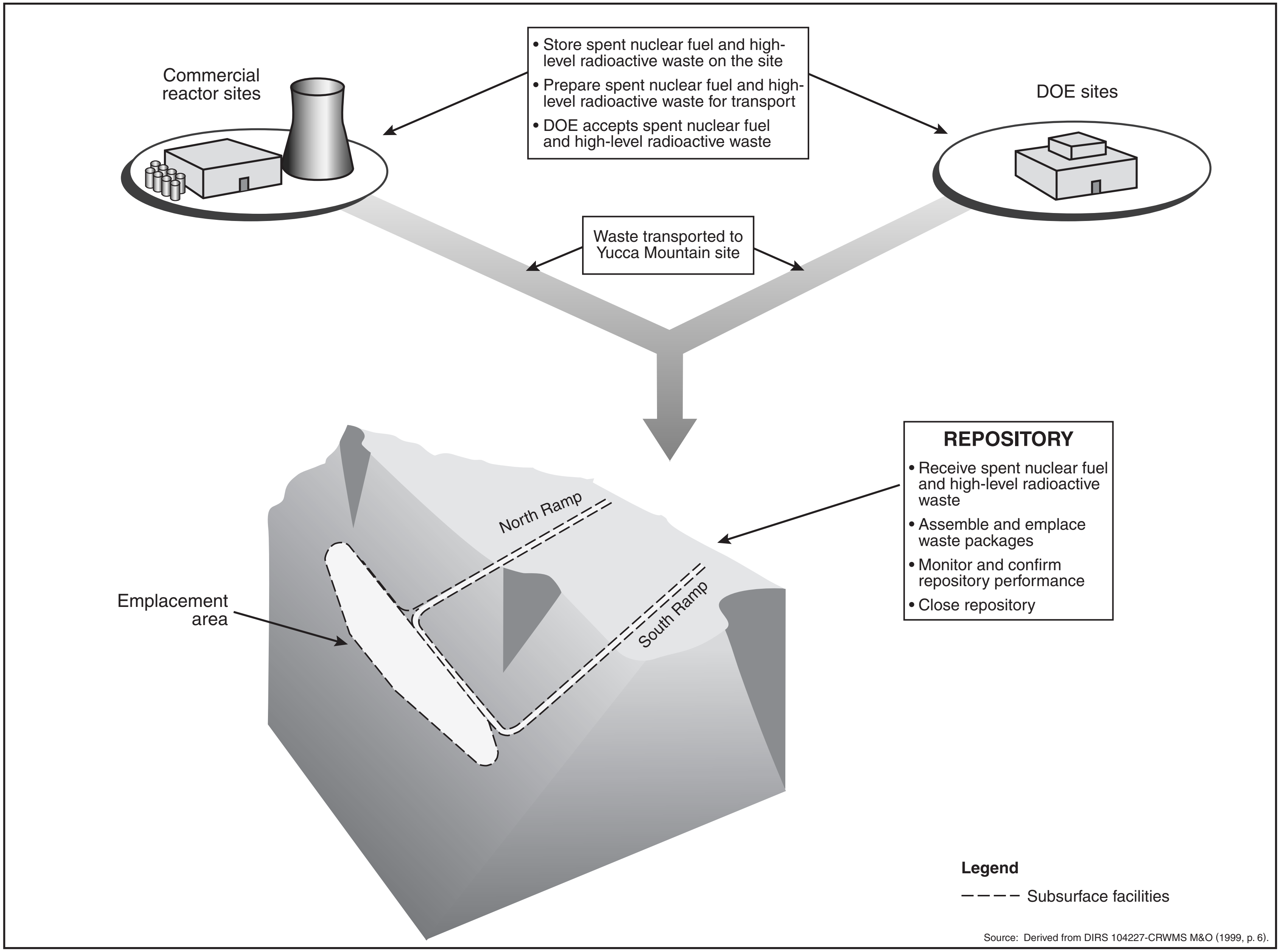


Figure 1-7. Spent nuclear fuel and high-level radioactive waste temporary storage, transportation, and disposal.

1.4.3 DOE ACTIONS TO EVALUATE THE YUCCA MOUNTAIN SITE

DOE has performed site characterization activities at Yucca Mountain for almost two decades, and has issued several documents related to those studies, in addition to the Draft EIS, Supplement to the Draft EIS, and this Final EIS, that would form part of the basis for a potential Site Recommendation. The following sections address these activities and reports, and provide a brief description of the No-Action Alternative.

1.4.3.1 Site Characterization Activities

In accordance with the NWPA [Section 113(b)], the DOE Office of Civilian Radioactive Waste Management prepared a Site Characterization Plan for the Yucca Mountain site (DIRS 100282-DOE 1988, all). DOE has had a program of investigations and evaluations to assess the suitability of the Yucca Mountain site as a potential geologic repository and to provide information for this EIS. The program consists of scientific, engineering, and technical studies and activities.

Examples of activities, investigations, and evaluations associated with site characterization include the following:

- Construction of an *Exploratory Studies Facility,* including the North and South *Portal* Ramps (openings into the mountain)
- Excavation of underground tunnels and rooms in the Exploratory Studies Facility for scientific and engineering studies, testing, and experiments
- Investigations of such topics as *hydrology,* including groundwater characteristics; general site geology; and specific geologic issues such as erosion, *seismicity,* and volcanic activity
- Field monitoring, including *air quality,* meteorological, radiological, and water resources monitoring
- Cultural resources studies, including Native American interests
- Terrestrial ecosystem studies

1.4.3.2 Viability Assessment

In the *Viability Assessment of a Repository at Yucca Mountain (Viability Assessment)* (DIRS 101779-DOE 1998, all), DOE evaluated a preliminary design based on scenarios that focused on the amount of spent nuclear fuel (and associated thermal output) that DOE would emplace per unit area of the repository. This concept was called *areal mass loading*. For analytical purposes, areal mass loading was represented in the Viability Assessment and in the Draft EIS by a high thermal load scenario, an intermediate thermal load scenario, and a low thermal load scenario. DOE selected these scenarios to represent the range of foreseeable design alternatives, and to ensure that it considered the associated range of potential environmental impacts. The Viability Assessment included the following:

- Preliminary design scenarios for critical elements of the repository and *waste package*
- A *total system performance assessment,* based on the design concept and the scientific data and analyses available by 1998, that described the probable behavior of the repository in the Yucca Mountain geologic setting

- A plan and cost estimate for the remaining work required to complete and submit a License Application to the Nuclear Regulatory Commission

- An estimate of the costs to construct and operate the repository in accordance with the design concept

The Draft EIS summarized results from the Viability Assessment, where applicable. DOE did not intend the scenarios studied in the Viability Assessment to place limits on choices among alternative designs. DOE expected the repository design to continue to evolve in response to ongoing site characterization and design-related evaluations.

1.4.3.3 Yucca Mountain Science and Engineering Report

Since the publication of the Draft EIS, DOE has continued to evaluate design features and operating modes that would improve long-term repository performance, reduce uncertainties in performance, and improve operational safety and efficiency. DOE documented the design evolution process in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (Science and Engineering Report; DIRS 153849-DOE 2001, all). The result of the process was the Science and Engineering Report Flexible Design (which this Final EIS calls the *flexible design*). DOE evaluated the flexible design in a Supplement to the Draft EIS, released for public review and comment in May 2001.

The Yucca Mountain Science and Engineering Report describes:

- Waste forms to be disposed of

- Results of scientific and engineering studies completed to date

- The flexible design for the repository (preliminary engineering specifications)

- A range of repository operating modes under the flexible design

- Waste package designs (preliminary engineering specifications)

- Results of recent assessments of the long-term performance of the potential repository (Total System Performance Assessment)

The Science and Engineering Report documents information that the Secretary of Energy will use to determine whether to recommend approval of the Yucca Mountain site to the President, including scientific investigations, site characterization studies, and evaluation of how conditions might evolve over time. In the flexible design, the basic elements of the proposed action, to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain remain unchanged. The flexible design provides the capability to operate the repository in a range of operating modes to affect conditions of temperature and associated humidity. The *higher-temperature repository operating mode* would raise at least portions of the rock walls between the emplacement drifts to a maximum temperature above 96ºC (205ºF), which is the boiling point of water at the repository elevation. The *lower-temperature operating mode* incorporates a range of scenarios that include conditions under which the surface temperature of emplaced waste packages would not exceed 85ºC (185ºF).

The Science and Engineering Report was issued in May 2001 for public comment. At the time of preparation of this Final EIS, DOE was revising this report to address these comments.

1.4.3.4 Preliminary Site Suitability Evaluation

Following the Science and Engineering Report, DOE released the *Yucca Mountain Preliminary Site Suitability Evaluation* (DIRS 155734-DOE 2001, all). The Preliminary Site Suitability Evaluation presents currently available information to support a preliminary evaluation of the suitability of the Yucca Mountain site for a monitored geologic repository and describes preliminary results of DOE's evaluation of whether the site is suitable for such a repository.

The Preliminary Site Suitability Evaluation compares the preliminary results of DOE's evaluation with DOE's proposed (since promulgated) site suitability guidelines. These preliminary results indicated that a potential repository at Yucca Mountain would likely meet Environmental Protection Agency radiation protection standards and proposed (since promulgated) Nuclear Regulatory Commission regulations for protecting people and the environment.

The purpose of the information provided in the Preliminary Site Suitability Evaluation is to aid the public in its review and comments on this aspect of the bases for the Secretary of Energy's consideration of a possible Site Recommendation.

The Preliminary Site Suitability Evaluation was issued in August 2001 for public comment. At the time of preparation of this Final EIS, DOE was revising this document to address these comments.

1.4.3.5 Supplemental Science and Performance Analyses

DOE has also issued the *Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, all; DIRS 154659-BSC 2001, all). This document describes supplemental analyses that have been conducted on long-term repository performance, incorporating those analyses into a supplemental Total Systems Performance Analysis (TSPA). The *Supplemental Science and Performance Analyses* first describes technical work conducted in each process model area and modifications to the Total System Performance Assessment model, and then describes the performance assessment analyses and results based on the technical work and model modification.

1.4.3.6 Total System Performance Assessment–Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain–Input to Final Environmental Impact Statement and Site Suitability Evaluation

DOE has issued the *Total System Performance Assessment – Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain – Input to Final Environmental Impact Statement and Site Suitability Evaluation* (DIRS 157307-BSC 2001, all). This assessment integrates information from all previous long-term performance models and provides further modification to the *Supplemental Science and Performance Analyses.* The results from this assessment, which are the most current available at the time of Final EIS production, directly support the long-term performance evaluation in the Final EIS.

1.4.3.7 Site Recommendation

Section 114(a) of the Nuclear Waste Policy Act requires that any recommendation by the Secretary of Energy be based on the record of information developed during site characterization and be submitted to the President together with a comprehensive statement of the basis of that recommendation. The recommendation is to be supported by:

- A description of the proposed repository, including preliminary engineering specifications for the facility

- A description of the *waste form* or packaging proposed for use at the repository, and an explanation of the relationship between such waste form or packaging and the geologic medium of the site

- A discussion of data obtained in site characterization activities that relate to the safety of the site

- A Final EIS prepared for the Yucca Mountain site accompanied by comments from the Department of the Interior, the Council on Environmental Quality, the Environmental Protection Agency, and the Nuclear Regulatory Commission

- The preliminary comments of the Nuclear Regulatory Commission on the extent to which the waste form proposal and the at-depth site characterization analysis seem to be sufficient for inclusion in a License Application

- The views and comments of the governor and legislature of any state and of the governing bodies of affected Native American tribes, together with responses from the Secretary of Energy to such views

- Any impact report submitted under Section 116(c)(2)(B) of the NWPA by the State of Nevada

- Other information the Secretary considers appropriate

1.4.3.8 No-Action Alternative

Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain and begin site *decommissioning* and reclamation. The commercial utilities and DOE would continue to store spent nuclear fuel and high-level radioactive waste. For purposes of analysis, the No-Action Alternative assumes that those sites would treat and package the materials, as necessary, in a condition ready for shipment to a repository. The potential environmental impacts from two No-Action scenarios, described below, serve as a basis for comparison to the potential environmental impacts of the Proposed Action.

- Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and DOE sites under *institutional control* for at least 10,000 years.

- Scenario 2 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and DOE sites in perpetuity, but under institutional control for only about 100 years. This scenario assumes no effective institutional control of the stored spent nuclear fuel and high-level radioactive waste after 100 years.

INSTITUTIONAL CONTROL

Monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements.

DOE recognizes that neither scenario would be likely if there was a decision not to develop a repository at Yucca Mountain; however, they are part of the EIS analysis to provide a basis for comparison to the Proposed Action. There are a number of possibilities that DOE could pursue, including continued storage of the material at its current locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository; development of new technologies; or reconsideration of alternatives to deep geologic disposal. One such centralized storage possibility, the proposed Private Fuel Storage Facility for commercial spent nuclear fuel in Utah, is currently in the Nuclear Regulatory Commission licensing process. The Commission issued a Final EIS in January 2002, however, that document was unavailable for use during the preparation of this Final EIS. The Commission has yet to issue a decision on whether to grant a license.

1.5 Environmental Impact Analysis Process

The National Environmental Policy Act of 1969, as amended, and regulations promulgated by the Council on Environmental Quality established procedures for Federal agencies to use when preparing an EIS. A major emphasis of the EIS process is to promote public awareness of the proposed actions and provide opportunities for public involvement. An agency prepares an EIS in a series of steps: (1) soliciting comments from Federal and state agencies, stakeholders, Tribal Nation representatives, and the general public to assist in defining the proposed action, alternatives, and issues requiring analysis (a process known as *scoping*); (2) preparing a Draft EIS for public distribution and comment; (3) receiving and responding to agency and public comments on the Draft EIS; and (4) preparing a Final EIS that incorporates or summarizes (if the public comments are exceptionally voluminous) and responds to public comments on the Draft EIS.

The NWPA includes specific provisions relevant to this EIS. Under the NWPA, the Secretary is not required to consider in this EIS (1) the need for a geologic repository, (2) the time at which a repository could become available, and (3) alternatives to isolating spent nuclear fuel and high-level radioactive waste in a repository. The fourth provision addresses the issue of potential alternative sites by providing that the EIS does not need to consider any site other than Yucca Mountain for repository development [NWPA, Section 114(f)(2) and (3)]. DOE has focused the EIS analysis on two alternatives: (1) the Proposed Action of constructing, operating and *monitoring,* and eventually closing a repository at Yucca Mountain, and (2) the No-Action Alternative, which assumes that site characterization activities at Yucca Mountain would end, and that spent nuclear fuel would remain at commercial sites and spent nuclear fuel and high-level radioactive waste would remain at DOE facilities.

1.5.1 DRAFT EIS AND SUPPLEMENT TO THE DRAFT EIS PROCESS

1.5.1.1 Notice of Intent and Scoping Meetings

The EIS scoping process is intended to determine the scope and the significant issues to be analyzed in depth in the EIS. The scoping process should begin early and be open, and include public notice of public meetings and of the availability of environmental documents to inform those persons and agencies who might be interested in or affected by a proposed action.

On August 7, 1995, DOE published a Notice of Intent announcing that it would prepare an EIS for a proposed repository at Yucca Mountain, Nevada (60 *FR* 40164, August 7, 1995). To encourage broad participation by the public, before publishing the Notice of Intent DOE notified its stakeholders, the media, Congressional representatives, the Office of the Governor of Nevada, affected units of local government in the Yucca Mountain site vicinity, the Nuclear Regulatory Commission, and other Federal agencies such as the Bureau of Land Management, National Park Service, and the Nuclear Waste Technical Review Board of its plans to prepare the EIS and its approach to the scoping process.

To reach minority and low-income communities, DOE contacted news publications and radio stations that tend to service these communities to notify them of the scoping meetings and the locations of available information. In addition, DOE met with 13 Native American tribes and organizations and provided them the same information. DOE invited public interest groups, transportation interests, industry and utility organizations, regulators, and members of the general public to participate in the process. The Department mailed a series of information releases to Yucca Mountain stakeholders notifying them of the opportunity to comment on the scope of the EIS; sent press releases and public service announcements to newspapers and television and radio stations; and made information about Yucca Mountain, the EIS, and the scoping process available on the Internet (at *www.ymp.gov*) and in public reading rooms around the country.

In 1995, DOE held 15 public scoping meetings across the country (DIRS 104630-YMP 1997, p. 7). More than 500 people submitted more than 1,000 comment documents during the 120-day public scoping period. DOE considered all comments—oral and written—it received during the scoping process and grouped them in categories in the *Summary of Public Scoping Comments Related to the Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DIRS 104630-YMP 1997, all).

PUBLIC SCOPING MEETING LOCATIONS

Sacramento, California
Denver, Colorado
College Park, Georgia (near Atlanta)
Boise, Idaho
Chicago, Illinois
Linthicum, Maryland (near Baltimore)
Kansas City, Missouri
Caliente, Nevada
Las Vegas, Nevada
Pahrump, Nevada
Reno, Nevada
Tonopah, Nevada
Troy, New York (near Albany)
Dallas, Texas
Salt Lake City, Utah

Several comments led to modifications in the scope of the EIS. The two most notable changes were the consideration of additional inventories such as the total projected inventory of spent nuclear fuel and high-level radioactive waste and other wastes that might require permanent isolation (see Section 1.5.1.2), and the addition of new Nevada transportation route alternatives. A number of commenters asked that the EIS discuss the history of the Yucca Mountain site characterization program and requirements of the NWPA; address DOE's responsibility to begin accepting waste in 1998 (including an analysis of the potential for receipt of spent nuclear fuel and high-level radioactive waste prior to the start of emplacement); describe the potential decisions that the EIS would support; and examine activities other than *construction, operation and monitoring,* and eventual closure of a repository at Yucca Mountain.

Other concerns raised by the public during scoping emphasized that DOE needed to ensure that the EIS thoroughly addresses the impacts of constructing and operating a geologic repository and related facilities (including the use of a rail line, heavy-haul truck routes, and intermodal transfer stations) on:

- Land uses in the Yucca Mountain vicinity (including consistency with existing land-use plans)
- Regional air quality and meteorology
- Geology (including the effects of earthquakes and volcanism and the potential for transport of radioactive and hazardous materials from the repository)
- Regional hydrology (including groundwater quality in Amargosa Valley, Ash Meadows, and Death Valley National Park)
- Biological resources (including postclosure effects on wildlife from potential increased surface temperatures)
- Health and safety (including past radiation exposures from activities at the Nevada Test Site for both pre- and postclosure periods)
- Long-term performance assessment for the repository (including an evaluation of the ability of the overall system to meet potential performance objectives, waste package performance and degradation given different thermal loads, *infiltration* rates, corrosion models, and other relevant factors)
- Sabotage and safeguards and security measures during waste transport and disposal

- Cultural and historic resources and *environmental justice*
- Socioeconomics
- *Mitigation* (including the mitigation of impacts from both routine operations and *accident* conditions)

DOE included discussions and analyses in the EIS that respond to these public issues and concerns.

DOE received many requests for more formal involvement in the EIS preparation process by representatives of the affected units of local government and Native American tribes. During the preparation of the EIS, DOE held discussions with a number of government agencies and other organizations to discuss issues of concern, obtain information for inclusion or analysis in the EIS, and initiate consultation or permit processes. DOE tasked (and funded) the American Indian Writers Subgroup to prepare a document setting forth Native American viewpoints and concerns regarding the repository and Yucca Mountain; that document (DIRS 102043-AIWS 1998, all) is quoted and referenced in the EIS. A similar opportunity was extended to the State of Nevada and the affected units of local government to prepare their own documents setting forth perspectives and views on a variety of issues of local and regional concern, which DOE agreed to incorporate by reference in the EIS. At the time the Draft EIS was issued, Nye County (DIRS 103099-Buqo 1999, all) had prepared such a document. In addition, other documents related to the Yucca Mountain region have been prepared in the past by several local government units including Clark, Lincoln, and White Pine Counties.

Some of the scoping comments raised issues and concerns that were not germane to the Proposed Action or the No-Action Alternative, such as the constitutional basis for waste disposal in Nevada. DOE acknowledged such issues and concerns in the summary of public scoping comments (DIRS 104630-YMP 1997, all), but did not analyze them in the EIS.

1.5.1.2 Additional Inventory Studies

The Proposed Action is to construct, operate and monitor, and eventually close a geologic repository for the disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. During the scoping period, DOE received many comments that noted the potential existence of more than 70,000 MTHM of these materials and encouraged DOE to evaluate the total projected inventory. For example, presently operating nuclear powerplants could generate approximately 105,000 MTHM of spent nuclear fuel eligible for disposal by 2046 if all currently operating commercial licenses were extended for 10 additional years. Recently approved license extensions have been for 20 years, but some plant licenses might not be extended. In addition, some commenters requested that the EIS evaluate the disposal of radioactive waste types that might require permanent isolation, such as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste. For these reasons, DOE has included in the EIS *cumulative impact* analysis an evaluation of the cumulative environmental impacts that could occur as a result of the disposal of all projected spent nuclear fuel and high-level radioactive waste and the disposal of quantities of Greater-Than-Class-C and Special-Performance-Assessment-Required waste in the Yucca Mountain Repository (see Chapter 8).

1.5.1.3 Additional Nevada Transportation Analyses

In response to public comments, DOE decided to analyze a fifth branch rail line and a fifth route for heavy-haul trucks in Nevada. The Department added analyses of the Caliente-Chalk Mountain branch rail line and the Caliente/Chalk Mountain route for heavy-haul trucks to the analyses of four rail corridors and four heavy-haul truck routes it had previously identified for potential transportation impacts in Nevada. Chapter 6 and Appendix J describe the transportation analyses. The U.S. Air Force opposes the use of

APPROXIMATE WASTE INVENTORIES
(Measurement methods differ among waste types)

Commercial spent nuclear fuel
- Projected total: 105,000 MTHM in 2046
- Current disposal plan: 63,000 MTHM (includes plutonium disposed of as mixed-oxide fuel)

DOE spent nuclear fuel
- Projected total: 2,500 MTHM
- Current disposal plan: 2,333 MTHM (one-third of the 7,000-MTHM total of DOE material proposed for disposal, which includes high-level radioactive waste)

High-level radioactive waste
- Projected total: 22,280 canisters (would include immobilized plutonium to be disposed of as stated in current disposal plans)
- Current disposal plan: 8,315 canisters (includes approximately one third of the surplus plutonium inventory)

Greater-Than-Class-C waste
- Projected total: 2,100 cubic meters
- Disposal evaluated in Chapter 8

Special-Performance-Assessment-Required waste
- Projected total: 4,000 cubic meters
- Disposal evaluated in Chapter 8

the Caliente-Chalk Mountain rail corridor and heavy-haul truck route because of national security concerns; at this time DOE regards these routes as nonpreferred alternatives.

1.5.1.4 Draft EIS Public Comment Process

On August 6, 1999, DOE issued the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. DOE made the document available in 38 reading rooms throughout the country, sent copies to those who requested them, and made an electronic copy available on the Internet. On the same day, the Department began a public comment period on the Draft EIS originally scheduled to end on February 9, 2000, and later extended until February 28, 2000. DOE accepted all comments on the Draft EIS, including written, oral, and electronic comments through August 31, 2001. DOE held public hearings in 21 locations across the country and throughout the State of Nevada and also held a hearing in Las Vegas to take comments from members of Native American Tribes in the region. More than 700 persons provided formal comments at those hearings. In total, DOE received more than 11,000 comments from more than 2,300 commenters on the Draft EIS.

Draft EIS Public Hearing Locations

Amargosa Valley, Nevada
Goldfield, Nevada
College Park (Atlanta), Georgia
Austin, Nevada
Boise, Idaho
Caliente, Nevada
Carson City, Nevada
Chicago, Illinois
Cleveland, Indiana
Crescent Valley, Nevada
Denver, Colorado
Ely, Nevada
Las Vegas, Nevada
Lincoln, Nebraska
Lone Pine, California
Pahrump, Nevada
Reno, Nevada
Salt Lake City, Utah
San Bernardino, California
St. Louis, Missouri
Washington, DC

DOE has prepared a Comment-Response Document (Volume III of this Final EIS) that addresses the issues raised during the public comment period. The Comment-Response Document contains each comment (as an individual comment or summarized with similar comments) and the DOE response to each comment. DOE has incorporated changes to the Draft EIS analysis resulting from the comments in this Final EIS.

1.5.1.5 Supplement to the Draft EIS

As DOE anticipated and described in the Draft EIS, the design for the proposed repository continued to evolve. To present the latest design information to *decisionmakers* and the public, on May 11, 2001, DOE issued the *Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada,* and began a 45-day public comment period on the Supplement. Based on requests from a variety of sources, the Department subsequently extended the comment period until July 6, 2001. In June, 2001, during a review of its administrative records, DOE discovered that it had inadvertently not sent the Supplement to the Draft EIS to about 700 stakeholders who had requested and received a copy of the Draft EIS. The Department announced this oversight (66 *FR* 34623; June 29, 2001), sent the Supplement to the Draft EIS to these stakeholders, and provided them an opportunity to submit comments during a separate 45-day comment period (June 29 to August 13, 2001). DOE has presented and responded to all comments on the Supplement to the Draft EIS received by August 31, 2001. All comments received after August 31, 2001, were responded to as time and resources permitted. However, all comments received after August 31, 2001, whether or not responded to, were considered by the Department. Based on this consideration, the Department concluded that none raised new issues not already reflected in timely comments and already considered.

The scope of the Supplement was limited to presenting the latest design information and presenting the expected environmental impacts that could result from the evolved design. DOE held three public hearings on the Supplement to the Draft EIS. The Department received approximately 1,900 written, oral, and electronic comments on the Supplement. The Final EIS incorporates the information from the Supplement. The Comment-Response Document (Volume III of this Final EIS) includes public comments on the Supplement, and responses to those comments. Changes to the analysis of the proposed repository project caused by those comments and responses are captured in Volumes I, II, and IV.

Supplement to the Draft EIS Public Hearing Locations

Amargosa Valley, Nevada
Las Vegas, Nevada
Pahrump, Nevada

1.5.2 CONFORMANCE WITH DOCUMENTATION REQUIREMENTS

DOE has performed formal documented reviews of data to identify gaps, inconsistencies, omissions, or other conditions that would cause data to be suspect or unusable.

DOE planned analyses to ensure consistency and thoroughness in the environmental studies conducted for this EIS. DOE has also used configuration control methods to ensure that EIS inputs are current, correct, and appropriate, and that outputs reflect the use of appropriate inputs.

All work products for this EIS have undergone documented technical, editorial, and managerial reviews for adequacy, accuracy, and conformance to project and DOE requirements. Work products related to impact analyses (for example, calculations, data packages, and data files) have also undergone formal technical and managerial reviews. Calculations (manual or computer-driven) generated to support impact analyses have been verified in accordance with project management procedures.

1.5.3 RELATIONSHIP TO OTHER ENVIRONMENTAL DOCUMENTS

A number of completed, in-preparation, or proposed DOE National Environmental Policy Act documents relate to this EIS. In addition, other Federal agencies have prepared related EISs. Consistent with Council on Environmental Quality regulations that implement the National Environmental Policy Act, DOE has used information from these documents in its analysis and has incorporated this material by reference as appropriate throughout this EIS. Table 1-1 lists the documents that formed a basis for decisions associated with a geologic disposal program and investigation of Yucca Mountain as a potential repository site; these include the EIS for Management of Commercially Generated Radioactive Waste (DIRS 104832-DOE 1980, all), the Surplus Plutonium Disposition EIS (DIRS 118979-DOE 1999, all), and the Yucca Mountain Site Environmental Assessment (DIRS 100136-DOE 1986, all).

Table 1-1. National Environmental Policy Act documents and Records of Decision related to the proposed Yucca Mountain Repository[a] (page 1 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Nuclear materials activities		
Final EIS, Management of Commercially Generated Radioactive Waste (DIRS 104832-DOE 1980, all)	Commercial SNF; DOE SNF and HLW	Examines different disposal alternatives. ROD documented DOE decision to pursue geologic disposal for SNF and HLW.
EA, Yucca Mountain Site, Nevada Research and Development Area (DIRS 100136-DOE 1986, all)	Commercial SNF; DOE SNF and HLW	Examines impacts of site characterization activities and possible geologic repository at Yucca Mountain.
Final Supplemental EIS, Defense Waste Processing Facility, Savannah River Site, Aiken, South Carolina (DIRS 103191-DOE 1994, all)	HLW	Examines impacts of constructing and operating DWPF, which processes HLW at SRS. SRS HLW could be eligible for repository disposal.
Final EIS, Waste Management, Savannah River Site (DIRS 103207-DOE 1995, all)	HLW	Examines impacts of managing five types of waste (including liquid HLW) at SRS over 10 years. SRS HLW could be eligible for repository disposal.
Final EIS, Interim Management of Nuclear Materials at the Savannah River Site (DIRS 103209-DOE 1995, all)	HLW	Examines impacts of stabilization and interim storage of plutonium, uranium, and other nuclear materials. SRS SNF and HLW could be eligible for repository disposal.
Final EIS, Management of Spent Nuclear Fuel from the K-Basins at the Hanford Site, Richland, Washington (DIRS 103213-DOE 1996, all)	DOE SNF	Examines impacts of managing SNF in K-Basins at Hanford. Hanford SNF could be eligible for repository disposal.
Draft EIS, Completion of the West Valley Demonstration Project and Closure or Long-Term Management of Facilities at the Western New York Nuclear Service Center (DIRS 101729-DOE 1996, all)	HLW	Examines impacts of solidifying liquid HLW obtained from reprocessing commercial SNF. WVDP HLW could be eligible for repository disposal.
Final EIS, Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (DIRS 101812-DOE 1996, all)	DOE SNF	Examines impacts of managing SNF from foreign research reactors in accordance with U.S. policy to reduce nuclear weapons proliferation. SNF from foreign research reactors stored at SRS and INEEL could be eligible for repository disposal.
Final EIS, Hanford Site Tank Waste Remediation System (DIRS 103214-DOE 1996, all)	HLW	Examines impacts of long-term management and disposal of Hanford tank waste, including HLW. Hanford HLW could be eligible for repository disposal.
Final EIS, Surplus Plutonium Disposition (DIRS 118979-DOE 1999, all)	Plutonium	Examines the alternatives for and impacts of disposition of surplus plutonium and of using mixed oxide fuel in six reactors. Ultimate disposition of the plutonium could involve repository disposal.
Draft EIS, Idaho High-Level Waste and Facilities Disposition (DIRS 155100-DOE 1999, all)	HLW	Examines impacts of treatment, storage, and disposal of INEEL HLW and facilities disposition. INEEL HLW could be eligible for repository disposal.
Final EIS, Savannah River Site Spent Nuclear Fuel Management (DIRS 156897-DOE 2000, all)	DOE SNF	Examines impact of several technologies for management of SNF at SRS, including placing these materials in forms suitable for ultimate disposition. Information from this EIS aids the study of packaging, transportation, and disposition of SNF.

Table 1-1. National Environmental Policy Act documents and Records of Decision related to the proposed Yucca Mountain Repository[a] (page 2 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Nuclear materials activities (continued)		
Record of Decision (62 *FR* 1095; January 8, 1997) and the Second Record of Decision (62 *FR* 23770; May 1, 1997) for a Container System for the Management of Naval Spent Nuclear Fuel Final EIS (DIRS 101941-USN 1996, all)	DOE SNF	Evaluates potential impacts of using alternative container systems for management of naval SNF following examination at INEEL. Naval SNF processed and stored at INEEL could be eligible for repository disposal. DOE used information from this EIS to estimate impacts from manufacture of disposal containers and shipping casks.
Supplement Analysis for a Container System for the Management of DOE Spent Nuclear Fuel Located at INEEL (DIRS 103230-DOE 1999, all)	DOE SNF	Determines the use of a multipurpose canister or comparable system for the management of DOE SNF at INEEL that might be suitable for shipment using existing transportation casks.
Record of Decision for a Multi-Purpose Canister or Comparable System for Idaho National Engineering and Environmental Laboratory Spent Nuclear Fuel (64 *FR* 23825; May 4, 1999)	DOE SNF	Determines that multi-purpose canisters or comparable systems will be used for loading, storage, and transportation outside the State of Idaho of most DOE SNF located at INEEL.
Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report NUREG-1437 (DIRS 101899-NRC 1996, all; DIRS 101900-NRC 1996, all) and the Draft Supplement for the Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Addendum 1 (DIRS 148185-NRC 1999, all)	Commercial SNF	Addresses the cumulative impacts of transportation of commercial spent nuclear fuel in the vicinity of the proposed repository at Yucca Mountain, Nevada, and the impacts of transporting higher-burnup fuel.
Record of Decision for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel (65 *FR* 56565; September 19, 2000)	Sodium-bonded SNF	Determines that electrometallurgical processing will be used to treat sodium-bonded SNF other than SNF from Fermi-1.
Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Nuclear Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah (DIRS 152001-NRC 2000, all).	Commercial SNF	The proposal of Private Fuel Storage, L.L.C. (PFS) to construct and operate an independent spent fuel storage installation on the Reservation of the Skull Valley Band of Goshute Indians.
Programmatic examination of waste management		
Record of Decision (DIRS 103205-DOE 1995, all) for the Final Programmatic EIS, Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs (DIRS 101802-DOE 1995, all)	DOE SNF	Examines programmatic impacts of storage of DOE SNF that could be eligible for repository disposal. In the associated ROD, DOE decided where DOE SNF would be managed.
Final Programmatic EIS, Storage and Disposition of Weapons-Usable Fissile Materials (DIRS 103215-DOE 1996, all)	DOE SNF and HLW	Examines impacts of long-term storage of plutonium and highly enriched uranium at several DOE sites. Spent mixed-oxide fuel and immobilized plutonium could be eligible for repository disposal.

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Table 1-1. National Environmental Policy Act documents and Records of Decision related to the proposed Yucca Mountain Repository[a] (page 3 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Programmatic examination of waste management (continued)		
Final Programmatic EIS, Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DIRS 101816-DOE 1997, all)	HLW	Examines impacts of managing five types of waste at DOE sites. Examines storage of HLW canisters and transportation of HLW canisters between DOE sites and Yucca Mountain.
Final EIS, Nevada Test Site and Off-Site Locations in the State of Nevada (DIRS 101811-DOE 1996, all)		Examines potential impacts of future mission activities at NTS. DOE used information from NTS EIS for Yucca Mountain site description and environmental impacts of NTS waste management activities. Cumulative impact analysis included activities analyzed in NTS EIS.
Regional description and cumulative impact information		
Final EIS, Withdrawal of Public Lands for Range Safety and Training Purposes at Naval Air Station Fallon, Nevada (DIRS 148199-USN 1998, all)		Examines impacts of land withdrawal around Naval Air Station Fallon. Repository EIS analysis of cumulative impacts considered proposed actions at Naval Air Station Fallon.
Legislative EIS for Nellis Air Force Range Renewal (DIRS 103472-USAF 1999, all)		Examines impacts of renewal of land withdrawal for Nellis Air Force Range. Yucca Mountain site is partly on range, and Repository EIS considers proposed actions at Nellis in its cumulative impacts analysis.
Proposed Caliente Management Framework Plan Amendment and FEIS for the Management of Desert Tortoise Habitat (DIRS 103080-BLM 1999, all)		Examines the implementation of BLM management goals and actions for the administration of the desert tortoise habitat in Lincoln County, Nevada.
Final EIS for the Cortez Pipeline Gold Deposit (DIRS 103078-BLM 1996, all)		Examines potential for impacts from mining-related activities at a location in north central Nevada.
EA, Pipeline Infiltration Project (DIRS 103081-BLM 1999, all)		Examines potential for impacts from mining-related activities at a location in north central Nevada.
Final Legislative Environmental Impact Statement, Timbisha Shoshone Homeland (DIRS 154121-DOI 2000, all)		Examines the potential for impacts from creating a Timbisha Shoshone Tribal reservation in and around Death Valley National Park.
Draft Environmental Impact Statement for the Proposed Relocation of Technical Area 18 Capabilities and Materials (DIRS 156910-DOE 2001, all)		Evaluates the environmental impacts associated with relocating the TA-18 capabilities and materials (presently located at Los Alamos) to each of four alternative sites, including NTS.

a. Abbreviations: BLM = Bureau of Land Management; DOE = U.S. Department of Energy; DOI = Department of the Interior; DWPF = Defense Waste Processing Facility; EA = environmental assessment; EIS = environmental impact statement; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory; NTS = Nevada Test Site; ROD = Record of Decision; SNF = spent nuclear fuel; SRS = Savannah River Site; WVDP = West Valley Demonstration Project.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

102043 AIWS 1998 — AIWS (American Indian Writers Subgroup) 1998. *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement.* Las Vegas, Nevada: Consolidated Group of Tribes and Organizations. ACC: MOL.19980420.0041.

104315 Barrett 1998 — Barrett, L. 1998. *Program Briefing for the U.S. Chamber of Commerce Energy and Natural Resources Committee, November 9, 1998.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19990526.0026.

103078 BLM 1996 — BLM (Bureau of Land Management) 1996. *Cortez Pipeline Gold Deposit: Final Environmental Impact Statement - Volume I.* Battle Mountain, Nevada: Bureau of Land Management. TIC: 242970.

103080 BLM 1999 — BLM (Bureau of Land Management) 1999. *Proposed Caliente Management Framework Plan Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat.* Ely, Nevada: U.S. Bureau of Land Management. TIC: 244133.

103081 BLM 1999 — BLM (Bureau of Land Management) 1999. *Cortez Gold Mines, Inc. Pipeline Infiltration Project.* Environmental Assessment NV063-EA98-062. Battle Mountain, Nevada: Bureau of Land Management. TIC: 243547.

154659 BSC 2001 — BSC (Bechtel SAIC Company) 2001. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.

155950 BSC 2001 — BSC (Bechtel SAIC Company) 2001. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010801.0404; MOL.20010712.0062; MOL.20010815.0001.

157307 BSC 2001 — BSC (Bechtel SAIC Company) 2001. *Total System Performance Assessment–Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain–Input to Final Environmental Impact Statement and Site Suitability Evaluation.* REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Co., LLC. ACC: MOL.20011213.0056.

103099	Buqo 1999	Buqo, T.S. 1999. *Nye County Perspective: Potential Impacts Associated With the Long-Term Presence of a Nuclear Repository at Yucca Mountain, Nye County, Nevada.* Pahrump, Nevada: Nye County Nuclear Waste Repository Office. TIC: 244065.
104227	CRWMS M&O 1999	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1999. *Reference Design Description for a Geologic Repository.* B00000000-01717-5707-00002 REV 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990301.0225. In the Draft EIS, this reference was cited as DOE 1999a in Chapter 12.
104832	DOE 1980	DOE (U.S. Department of Energy) 1980. *Final Environmental Impact Statement Management of Commercially Generated Radioactive Waste.* DOE/EIS-0046F. Three volumes. Washington, D.C.: U.S. Department of Energy, Office of Nuclear Waste Management. ACC: HQZ.19870302.0183; HQZ.19870302.0184; HQZ.19870302.0185.
100136	DOE 1986	DOE (U.S. Department of Energy) 1986. *Environmental Assessment Yucca Mountain Site, Nevada Research and Development Area, Nevada.* DOE/RW-0073. Three volumes. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQZ.19870302.0332.
100282	DOE 1988	DOE (U.S. Department of Energy) 1988. *Site Characterization Plan Yucca Mountain Site, Nevada Research and Development Area, Nevada.* DOE/RW-0199. Nine volumes. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQO.19981201.0002.
103191	DOE 1994	DOE (U.S. Department of Energy) 1994. *Final Supplemental Environmental Impact Statement, Defense Waste Processing Facility.* DOE/EIS-0082-S. Aiken, South Carolina: U.S. Department of Energy. TIC: 243608.
101802	DOE 1995	DOE (U.S. Department of Energy) 1995. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement.* DOE/EIS-0203-F. Idaho Falls, Idaho: U.S. Department of Energy, Idaho Operations Office. TIC: 216020.
103205	DOE 1995	DOE (U.S. Department of Energy) 1995. *Record of Decision – Department of Energy Programmatic Spent Nuclear Fuel Management and the Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs.* Idaho Falls, Idaho: U.S. Department of Energy. TIC: 243787.

103207	DOE 1995	DOE (U.S. Department of Energy) 1995. *Savannah River Site, Waste Management, Final Environmental Impact Statement.* DOE/EIS-0217. Aiken, South Carolina: U.S. Department of Energy. TIC: 243607.
103209	DOE 1995	DOE (U.S. Department of Energy) 1995. *Final Environmental Impact Statement, Interim Management of Nuclear Materials, Savannah River Site, Aiken, South Carolina.* DOE/EIS-0220. Aiken, South Carolina: U.S. Department of Energy. TIC: 243411.
101729	DOE 1996	DOE (U.S. Department of Energy) 1996. *Draft Environmental Impact Statement for Completion of the West Valley Demonstration Project and Closure or Long-Term Management of Facilities at the Western New York Nuclear Service Center.* DOE/EIS-0226-D. Two volumes. Washington, D.C.: U.S. Department of Energy. TIC: 223997.
101811	DOE 1996	DOE (U.S. Department of Energy) 1996. *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada.* DOE/EIS 0243. Las Vegas, Nevada: U.S. Department of Energy, Nevada Operations Office. TIC: 239895.
101812	DOE 1996	DOE (U.S. Department of Energy) 1996. *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel.* DOE/EIS-0218F. Washington, D.C.: U.S. Department of Energy. TIC: 223998.
103213	DOE 1996	DOE (U.S. Department of Energy) 1996. *Addendum (Final Environmental Impact Statement), Management of Spent Nuclear Fuel from the K-Basins at the Hanford Site, Richland, Washington.* DOE/EIS-0245F. Richland, Washington: U.S. Department of Energy. TIC: 243958.
103214	DOE 1996	DOE (U.S. Department of Energy) 1996. *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement.* DOE/EIS-0189. Richland, Washington: U.S. Department of Energy. TIC: 226909.
103215	DOE 1996	DOE (U.S. Department of Energy) 1996. *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement.* DOE/EIS-0229. Summary and four volumes. Washington, D.C.: U.S. Department of Energy. TIC: 243897.
101816	DOE 1997	DOE (U.S. Department of Energy) 1997. *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste.* DOE/EIS-0200-F. Summary and five volumes. Washington, D.C.: U.S. Department of Energy, Office of Environmental Management. TIC: 232988.

101779 DOE 1998 — DOE (U.S. Department of Energy) 1998. *Viability Assessment of a Repository at Yucca Mountain.* DOE/RW-0508. Overview and five volumes. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19981007.0027; MOL.19981007.0028; MOL.19981007.0029; MOL.19981007.0030; MOL.19981007.0031; MOL.19981007.0032.

103230 DOE 1999 — DOE (U.S. Department of Energy) 1999. *Supplement Analysis for a Container System for the Management of DOE Spent Nuclear Fuel Located at the INEEL.* DOE/ID-10636. Idaho Falls, Idaho: U.S. Department of Energy. TIC: 244067.

118979 DOE 1999 — DOE (U.S. Department of Energy) 1999. *Surplus Plutonium Disposition Final Environmental Impact Statement.* DOE/EIS-0283. Washington, D.C.: U.S. Department of Energy, Office of Fissile Materials Disposition. TIC: 246385.

155100 DOE 1999 — DOE (U.S. Department of Energy) 1999. *Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement.* DOE/EIS-0287D. Idaho Falls, Idaho: U.S. Department of Energy, Idaho Operations Office. ACC: MOL.20001030.0151.

156897 DOE 2000 — DOE (U.S. Department of Energy) 2000. *Savannah River Site, Spent Nuclear Fuel Management Final Environmental Impact Statement.* DOE/EIS-0279F. Aiken, South Carolina: U.S. Department of Energy.

153849 DOE 2001 — DOE (U.S. Department of Energy) 2001. *Yucca Mountain Science and Engineering Report.* DOE/RW-0539. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0272.

155734 DOE 2001 — DOE (U.S. Department of Energy) 2001. *Yucca Mountain Preliminary Site Suitability Evaluation.* DOE/RW-0540. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20011101.0082.

156910 DOE 2001 — DOE (U.S. Department of Energy) 2001. *Draft Environmental Impact Statement for the Proposed Relocation of Technical Area 18 Capabilities and Materials at the Los Alamos National Laboratory - Summary.* DOE/EIS-319D. Washington, D.C.: United States Department of Energy: National Nuclear Security Administration.

154121 DOI 2000 — DOI (U.S. Department of the Interior) 2000. *Final Legislative Environmental Impact Statement, Timbisha Shoshone Homeland.* Three volumes. San Francisco, California: U.S. Department of the Interior, Timbisha Shoshone Tribe.

100018 National Research Council 1995 — National Research Council 1995. *Technical Bases for Yucca Mountain Standards.* Washington, D.C.: National Academy Press. TIC: 217588.

103414 NRC 1976 NRC (U.S. Nuclear Regulatory Commission) 1976. *Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors.* NUREG-0002. Executive Summary and five volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 243889.

101899 NRC 1996 NRC (U.S. Nuclear Regulatory Commission) 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report.* NUREG-1437, Vol. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 233963.

101900 NRC 1996 NRC (U.S. Nuclear Regulatory Commission) 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Appendices, Final Report.* NUREG-1437, Vol. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 233962.

148185 NRC 1999 NRC (U.S. Nuclear Regulatory Commission) 1999. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Section 6.3 - Transportation, Table 9.1 Summary of Findings on NEPA Issues for License Renewal of Nuclear Power Plants, Draft Report for Comment.* NUREG-1437, Vol. 1, Addendum 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 244062.

152001 NRC 2000 NRC (U.S. Nuclear Regulatory Commission) 2000. *Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah.* NUREG-1714. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. ACC: MOL.20000828.0030.

103472 USAF 1999 USAF (U.S. Air Force) 1999. *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement.* Washington, D.C.: U.S. Department of the Air Force. TIC: 243264.

101941 USN 1996 USN (U.S. Department of the Navy) 1996. *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel.* DOE/EIS-0251. Washington, D.C.: U.S. Department of Energy. TIC: 227671.

148199 USN 1998 USN (U.S. Department of the Navy) 1998. *Final Environmental Impact Statement (FEIS) for the Withdrawal of Public Lands for Range Safety and Training Purposes at Naval Air Station (NAS) Fallon, Nevada.* Fallon, Nevada: U.S. Department of the Navy. TIC: 243879.

104630 YMP 1997 YMP (Yucca Mountain Site Characterization Project) 1997. *Summary of Public Scoping Comments Related to the Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.* Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19970731.0515. In the Draft EIS, this reference was cited as DOE 1997a in Chapter 12.

2

Proposed Action and No-Action Alternative

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2. PROPOSED ACTION AND NO-ACTION ALTERNATIVE

Under the Proposed Action, the U.S. Department of Energy (DOE) would construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain (see Section 2.1). The Proposed Action includes transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the Yucca Mountain site (see Figure 2-1).

Under the No-Action Alternative (see Section 2.2), DOE would end site characterization activities at Yucca Mountain, and the commercial and DOE sites would continue to manage their spent nuclear fuel and high-level radioactive waste (see Figure 2-1). The No-Action Alternative assumes that spent nuclear fuel and high-level radioactive waste would be treated and packaged as necessary for its safe *onsite* management. DOE does not intend to represent the No-Action Alternative as a viable long-term solution but rather to use it as a basis against which the Proposed Action can be evaluated.

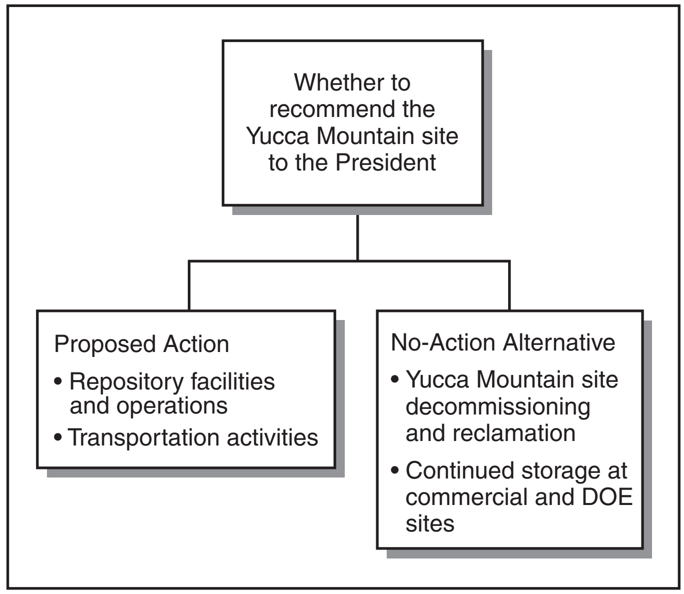


Figure 2-1. General activity areas evaluated under the Proposed Action and No-Action Alternative.

Section 2.3 discusses the alternatives that DOE considered but eliminated from detailed study in this environmental impact statement (EIS). Section 2.4 summarizes findings from the EIS and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative. Section 2.5 addresses the collection of information and analyses performed for the EIS. Section 2.6 identifies the preferred alternative.

DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the Nuclear Waste Policy Act, as amended (NWPA, 42 U.S.C 10101 *et. seq.*), in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

As part of the Proposed Action, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the impacts of truck and rail transportation nationally and in Nevada, as well as impacts in Nevada of alternative intermodal (rail-to-truck) transfer stations, associated routes for heavy-haul trucks, and alternative corridors for a branch rail line.

DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches to transportation (for example, rail or truck shipments), as well as the choice among alternative rail corridors in Nevada. However, follow-on implementing decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul truck routes, would require additional field surveys, State and local government and Native American tribal consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada. At this time, the Department has not identified a preference for a specific rail corridor in Nevada. If the Yucca Mountain site was recommended and approved, DOE would identify such a preference in consultation with affected stakeholders, particularly the State of Nevada. In this case, DOE would announce its preferred corridor in a *Federal Register* notice, and would publish its decision to select a corridor in a Record of Decision no sooner than 30 days after the announcement of a preference.

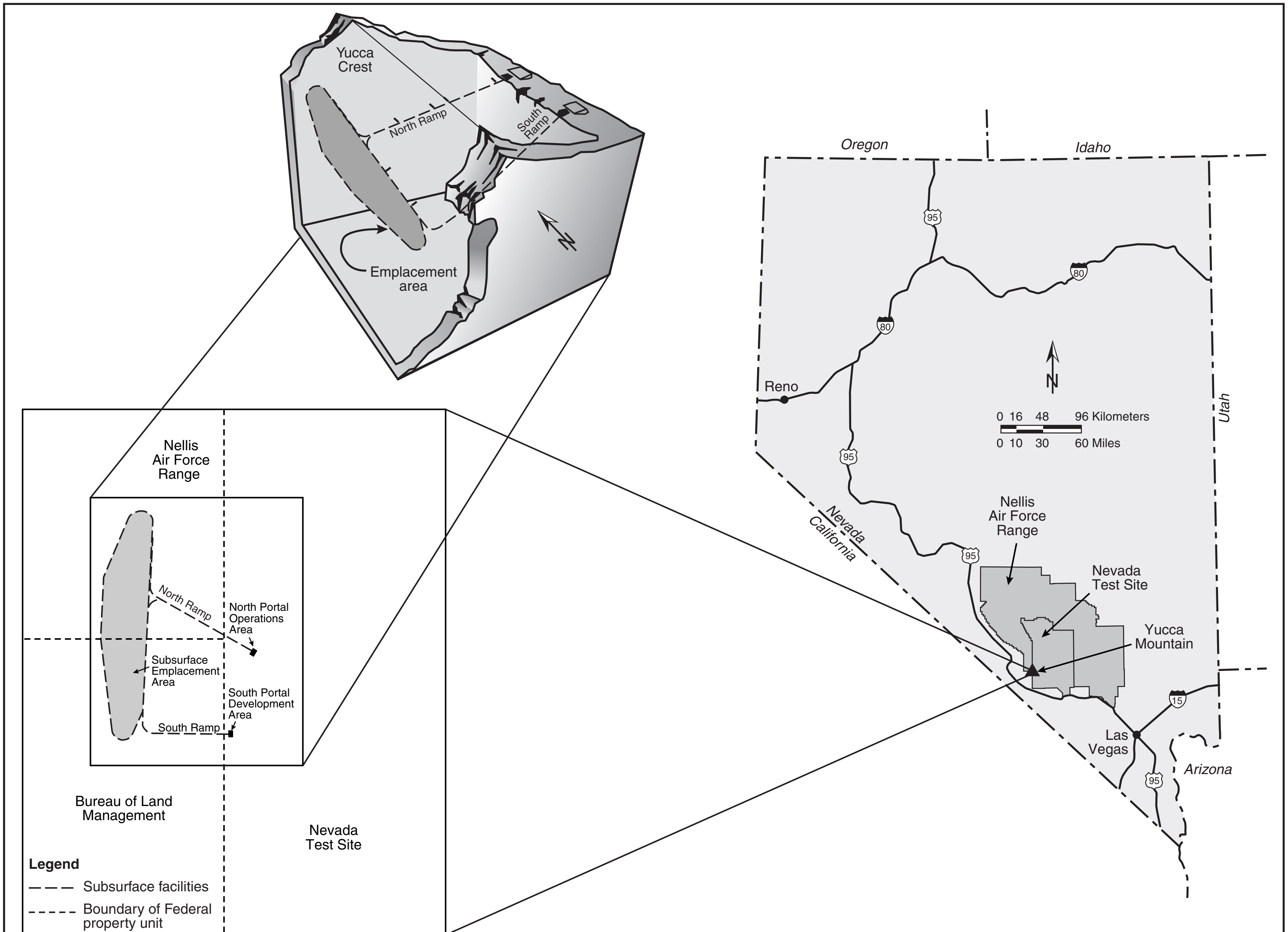
2.1 Proposed Action

DOE proposes to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of spent nuclear fuel and high-level radioactive waste. In its simplest terms, the proposed repository would be a large underground excavation with a network of *drifts* (tunnels) that DOE would use for spent nuclear fuel and high-level radioactive waste emplacement. About 600 square kilometers (230 square miles or 150,000 acres) of land in Nye County, Nevada, could be permanently withdrawn from public access for repository use. The proposed location of the repository is shown in Figure 2-2. DOE would dispose of spent nuclear fuel and high-level radioactive waste in the repository using the inherent, natural geologic features of the mountain and engineered (manmade) barriers to help ensure the long-term isolation of the spent nuclear fuel and high-level radioactive waste from the human environment. DOE would build the repository emplacement drifts inside Yucca Mountain at least 200 meters (660 feet) below the surface and at least 160 meters (530 feet) above the present-day *water table* (DIRS 154554-BSC 2001, pp. 28 and 29).

Under the Proposed Action, DOE would permanently place approximately 11,000 (DIRS 152010-CRWMS M&O 2000, p. 14) to 17,000 waste packages containing no more than 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain. Of the 70,000 MTHM to be emplaced in the repository, 63,000 MTHM would be spent nuclear fuel assemblies from boiling-water and *pressurized-water reactors* (Figure 2-3) that DOE would ship from commercial nuclear sites to the repository. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel and 8,315 canisters (4,667 MTHM) containing solidified high-level radioactive waste (see Figure 2-3) that the Department would ship to the repository from its facilities. The 70,000-MTHM inventory would include surplus weapons-usable plutonium as spent mixed-oxide fuel or immobilized plutonium. Appendix A contains additional information on the inventory and characteristics of spent nuclear fuel, high-level radioactive waste, and other materials that DOE could emplace in the proposed repository. For this EIS, a connected action includes the offsite manufacturing of the containers that DOE would use for the transport and disposal of spent nuclear fuel and high-level radioactive waste and the specialized titanium drip shields and corrosion-resistant emplacement pallets that DOE could install over and under, respectively, the waste packages to improve performance and to reduce *uncertainty* about the long-term performance of the repository.

DEFINITION OF METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.



Source: Modified from DIRS 104508-CRWMS M&O (1999, Attachment IV, Figure 1).

Figure 2-2. Diagram and location of the proposed repository at Yucca Mountain.

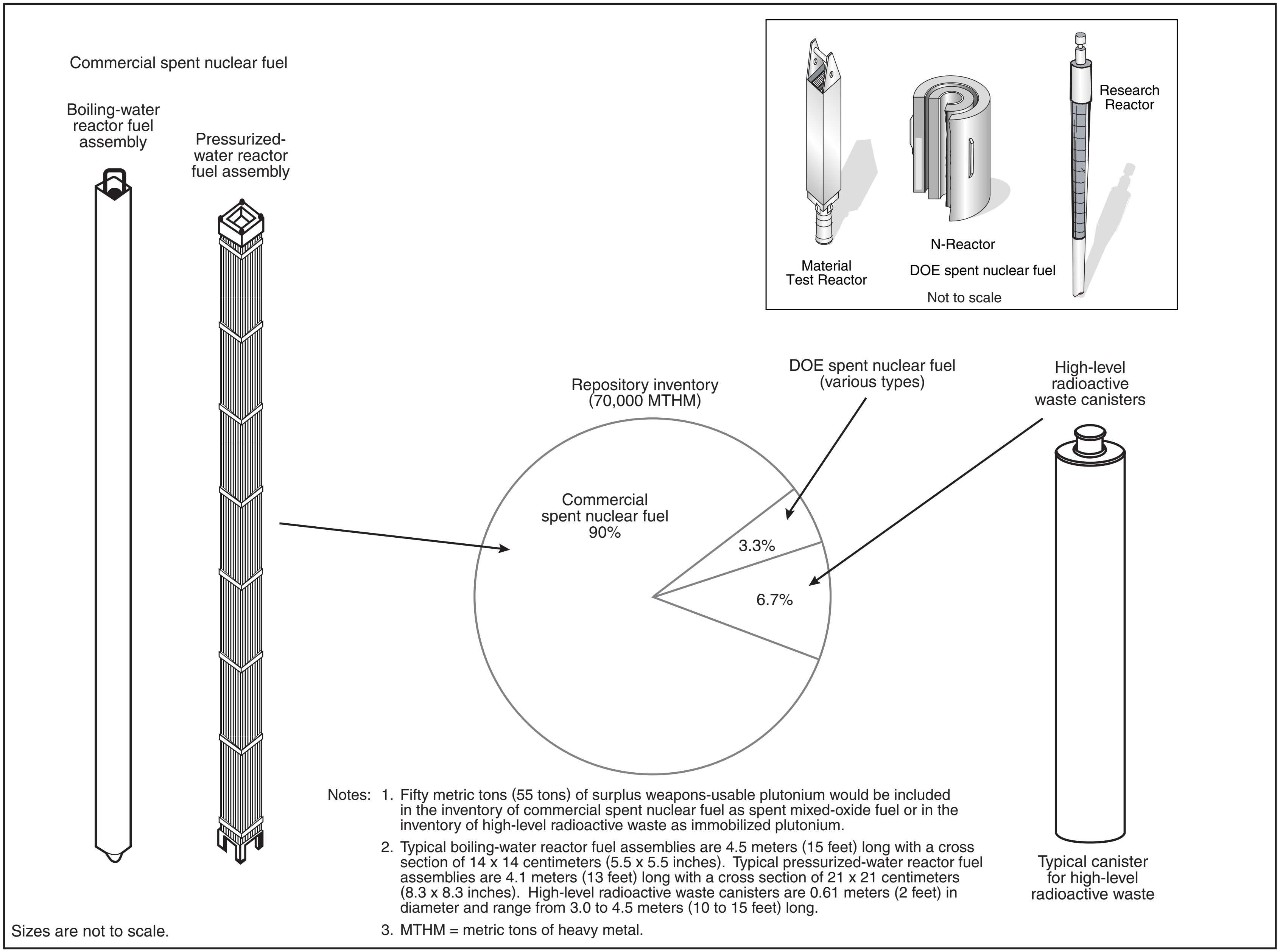


Figure 2-3. Sources of spent nuclear fuel and high-level radioactive waste proposed for disposal at the Yucca Mountain Repository.

Figure 2-4 is an overview of components or activities associated with the Proposed Action. The implementing alternatives and scenarios analyzed in this EIS, as described in Section 2.1.1, represent the potential range of variables associated with implementing the Proposed Action that could affect environmental impacts. The Proposed Action would require surface and subsurface facilities and operations for the receipt, packaging, possible surface *aging*, and emplacement of spent nuclear fuel and high-level radioactive waste (see Section 2.1.2) and transportation of these materials to the repository (see Section 2.1.3). Section 2.1.5 summarizes the estimated cost of the Proposed Action. Chapters 4, 5, and 6 evaluate potential environmental impacts from the Proposed Action. As part of the process to develop implementing concepts, mitigation techniques have been designed into the Proposed Action through the use of best engineering and management practices, as applicable.

The Proposed Action would use two types of institutional controls—active and passive. Active institutional controls (monitored and enforced limitations on site access; inspection and *maintenance* of waste packages, facilities, equipment, etc.) would be used through closure. Passive institutional controls (markers, engineered barriers, etc., that are not monitored or maintained) would be put in place during closure and used to minimize inadvertent exposures to members of the public in the future.

2.1.1 OVERVIEW OF IMPLEMENTING ALTERNATIVES AND SCENARIOS

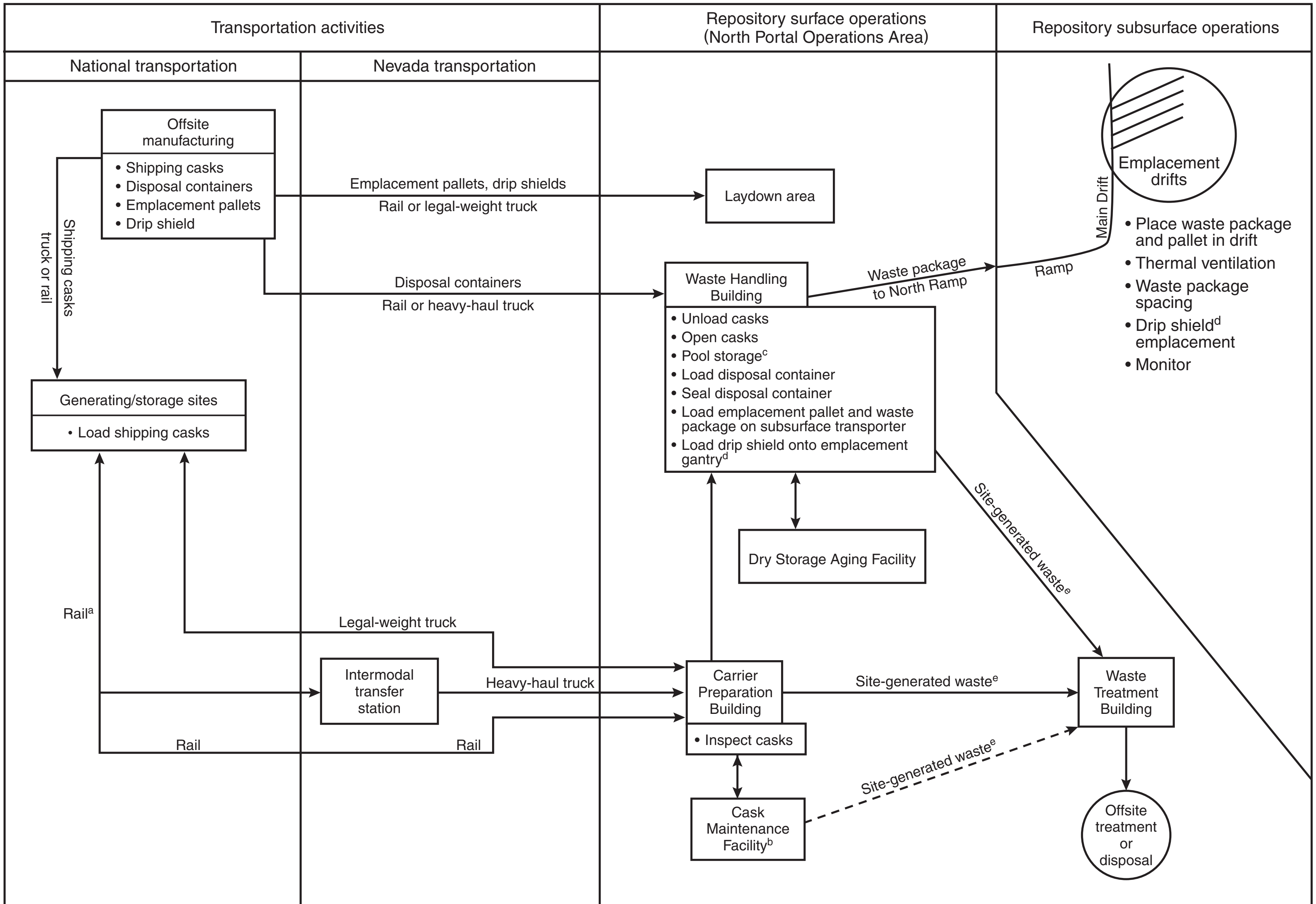
This EIS describes and evaluates the current preliminary design concept for repository surface facilities, subsurface facilities, and disposal containers (waste packages), and the current plans for the construction, operation and monitoring, and closure of the repository. DOE recognizes that plans for the repository would continue to evolve during the development of the final repository design and as a result of the U.S. Nuclear Regulatory Commission licensing review of the repository. While the design continues to evolve, it is based on decades of similar experience in mining operations and the management of spent nuclear fuel and other radioactive materials, as well as the ongoing site characterization and *performance confirmation* activities and results. In addition, decisions on how spent nuclear fuel and high-level radioactive waste would be shipped to the repository (for example, truck or rail) and how spent nuclear fuel would be packaged (*uncanistered* or in disposable or dual-purpose canisters) would be part of future transportation planning efforts.

DISPOSAL CONTAINERS AND WASTE PACKAGES

A *disposal container* is the vessel consisting of the barrier materials and internal components in which the spent nuclear fuel and high-level radioactive waste would be placed. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

For these reasons, DOE developed implementing alternatives and analytical scenarios to bound the environmental impacts likely to result from the Proposed Action in the EIS (see Figure 2-5). The Department selected the implementing alternatives and scenarios to accommodate and maintain flexibility for potential future revisions to the design and operation of the repository. Because of uncertainties, DOE selected implementing alternatives and scenarios that incorporate conservative assumptions that tend to overstate the risks to address those uncertainties.

The following paragraphs describe the packaging scenarios, repository operating modes, national transportation scenarios, Nevada transportation scenarios, and implementing rail and intermodal alternatives evaluated in the EIS.



a. Heavy-haul trucks or barges could be used to deliver spent nuclear fuel from generating/storage sites that did not have rail access to a nearby rail line.

b. For the EIS analysis, assumed to be at the repository.

c. Possible aging of commercial fuel for lower-temperature operating mode.

d. Drip shields emplaced during repository closure.

e. Or directly to offsite treatment or disposal.

Figure 2-4. Overview flowchart of the Proposed Action.

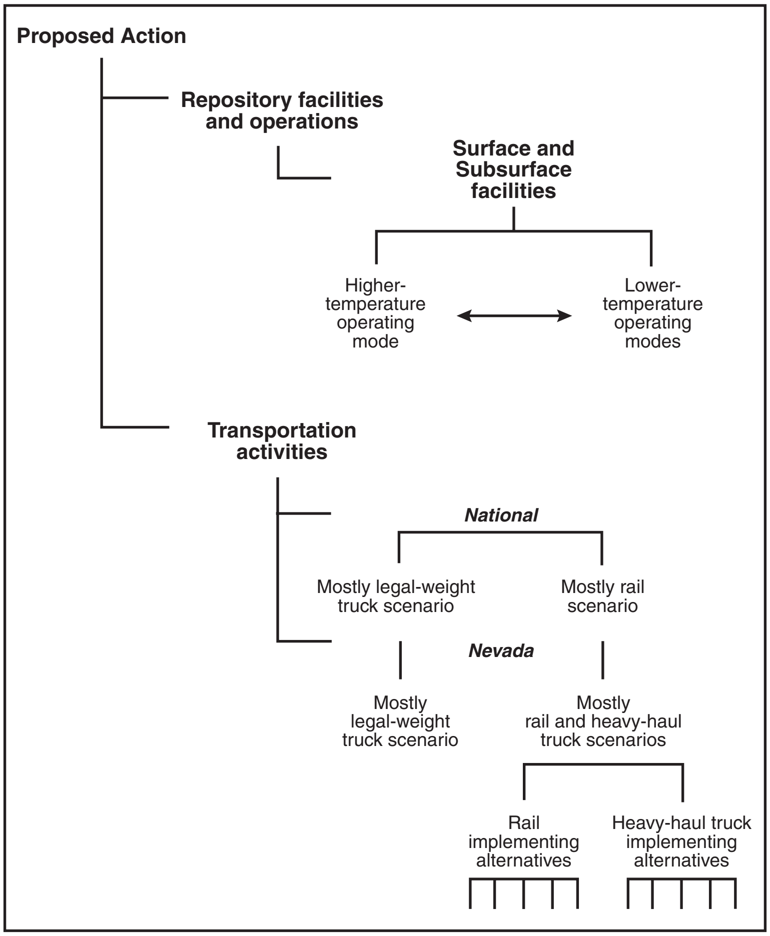


Figure 2-5. Analytical scenarios and implementing alternatives associated with the Proposed Action.

2.1.1.1 Packaging Scenarios

DOE operations at repository surface facilities would differ depending on how the spent nuclear fuel in shipping casks was packaged. Commercial spent nuclear fuel could be received either uncanistered or in disposable or dual-purpose canisters.

The EIS assumes that DOE spent nuclear fuel and high-level radioactive waste would be shipped to the repository in *disposable canisters*. In addition, it evaluates the following packaging scenarios for commercial spent nuclear fuel to cover the potential range of environmental impacts from repository surface facility construction and operation:

- A mostly uncanistered fuel scenario
- A mostly canistered fuel scenario

For this Final EIS, DOE simplified the presentation of the packaging scenarios that were analyzed in the Draft EIS by analyzing only one bounding packaging scenario (the Draft EIS considered both mostly canistered and uncanistered scenarios). DOE was able to simplify the presentation of impacts in the Final EIS because the Draft EIS analysis demonstrated that the mostly uncanistered fuel packaging scenario bounded the analysis in all cases with the exception of (1) the empty dual-purpose canisters that some commercial sites could use that would require disposal or recycling, and (2) some attributes of offsite manufacturing of the disposable canister. The presentation of potential impacts in Chapter 4 of this Final

DEFINITIONS OF PACKAGING TERMS

Shipping cask: A vessel that meets applicable regulatory requirements for shipping spent nuclear fuel or high-level radioactive waste.

Dual-purpose canister: A metal vessel suitable for storing (in a storage facility) and shipping (in a shipping cask) commercial spent nuclear fuel assemblies. At the repository, dual-purpose canisters would be removed from the shipping cask and opened. The spent nuclear fuel assemblies would be removed from the canister and placed in a disposal container or in the fuel pool to accommodate blending. The opened canister would be recycled or disposed of offsite as low-level radioactive waste.

Disposable canister: A metal vessel for commercial or DOE spent nuclear fuel assemblies or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, the disposable canister would be removed from the shipping cask and placed directly in a disposal container. The disposable canister is sometimes referred to as a multi-purpose canister in discussions of repository design.

Uncanistered spent nuclear fuel: Commercial spent nuclear fuel placed directly into shipping casks. At the repository, spent nuclear fuel assemblies would be removed from the shipping cask and placed in a disposal container or in the fuel pool to accommodate blending.

Disposal container: A container for spent nuclear fuel and high-level radioactive waste consisting of the barrier materials and internal components. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

Waste package: The filled, sealed, and tested disposal container that would be emplaced in the repository.

EIS primarily reports impacts associated with the mostly uncanistered scenario. Where the canistered scenario would result in greater impacts (that is, waste management and offsite manufacturing impacts), the greater impacts are provided. Therefore, the scenarios discussed in this Final EIS represent current design concepts and bound the impacts of any canister scenario, including the disposable canister scenario. DOE ultimately might select either scenario. For all scenarios, high-level radioactive waste and DOE spent nuclear fuel remain in the disposable canisters in which they were received for emplacement.

Table 2-1 summarizes these scenarios.

Table 2-1. Packaging scenarios (percentage based on number of shipments).

Material[a]	Mostly uncanistered fuel	Mostly canistered fuel
Commercial SNF	100% uncanistered fuel	About 80% dual-purpose canisters; about 20% uncanistered fuel
HLW	100% disposable canisters	100% disposable canisters
DOE SNF	100% disposable canisters	100% disposable canisters

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste.

2.1.1.2 Repository Operating Modes

The heat generated by spent nuclear fuel and high-level radioactive waste could affect the long-term performance of the repository (that is, the ability of the engineered and natural barrier systems to isolate the emplaced waste from the human environment). Different repository operating modes would have a direct effect on internal and external waste package temperatures, thereby potentially affecting the corrosion rate and integrity of the waste packages.

Parameters associated with maximum repository temperatures (see Table 2-2) are central to defining the operating modes of the flexible design. The repository temperature would depend on factors related to the design and operation of the repository including, but not limited to, the age and *burnup* of the spent nuclear fuel at the time of emplacement, the spacing of the emplacement drifts and the waste packages in them, and the repository ventilation method and duration. The implementation of these design and operational parameters would affect the short-term environmental impacts of the repository.

Table 2-2. Summary of key underground design and operating parameters associated with repository operating modes analyzed in the EIS.

		Repository operating mode	
Parameter	Unit of measure	Higher-temperature[a]	Lower-temperature[b]
Linear thermal load	Kilowatts per meter	1.42	0.65 to 1[c]
Drift spacing	Meters[d]	81	81[e]
Areal mass load	MTHM[f] per acre	56	25 to 39
Waste package spacing	Meters	0.1	0.1 to 6.4[e]
Emplacement duration	Years	24	24 (50)[g]
Preclosure ventilation duration[h]	Years	100	149 to 324
Closure duration	Years	10	11 to 17
Ventilation rate (forced)	Cubic meters[i] per second in drift	15	15
External ventilation shafts (emplacement and development)	Number	7	9 to 17
Dependent parameter			
Underground area	Square kilometers	4.7	6.5 to 10.1
Total excavated repository volume[j]	Millions of cubic meters	4.4	5.7 to 8.8
Waste packages	Number (in thousands)	11 to 12	11 to 17

a. Source: DIRS 150941-CRWMS M&O (2000, all).
b. Sources: DIRS 152003-McKenzie (2000, all); DIRS 153849-DOE (2001, all).
c. If commercial SNF is aged, linear thermal loads will be lower.
d. To convert meters to feet, multiply by 3.2808.
e. Drift spacing and waste package spacing determine various areal mass loads.
f. MTHM = metric tons of heavy metal.
g. The lower-temperature repository operating mode analysis assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period for scenarios that used aging at the repository.
h. From start of emplacement to start of repository closure.
i. To convert cubic meters to cubic feet, multiply by 35.314.
j. Includes existing Exploratory Studies Facility volume of 420,000 cubic meters (15 million cubic feet).

The basis for the three thermal load scenarios in the Draft EIS was the amount of commercial spent nuclear fuel that DOE would emplace per unit area of the repository (areal mass loading). These scenarios included a relatively high emplacement density of commercial spent nuclear fuel (high thermal load – 85 MTHM per acre), a relatively low emplacement density (low thermal load – 25 MTHM per acre), and an emplacement density between the high and low thermal loads (intermediate thermal load – 60 MTHM per acre).

Rather than focusing on thermal loads, the flexible design focuses on controlling the temperature of the rock between the drifts, and on the surface of the waste package and drift walls. The flexible design uses a *linear thermal load* (heat output per unit length of the emplacement drift) and emplaces waste packages closer together than the Draft EIS design. Linear thermal load is expressed in terms of kilowatts per meter.

The design discussed in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (DIRS 153849-DOE 2001, all) includes the ability to operate the repository in a range of modes that address higher and lower temperatures. *Higher-temperature* means that at least a portion of the emplacement drift rock wall would have a maximum temperature above the boiling point of water at the elevation of the repository [96°C (205°F)]. The *lower-temperature* operating mode ranges include conditions under which the drift rock wall temperatures would be below the boiling point of water, and conditions under which waste package surface temperatures would not exceed 85°C (185°F).

To construct the analytical basis for evaluation of repository impacts, DOE used widely accepted analytical tools, coupled with the best available information, and cautious but reasonable assumptions where uncertainties exist, to estimate potential environmental impacts. This included applying conservative assumptions to the set of reasonable operating scenarios identified in the Science and Engineering Report (DIRS 153849-DOE 2001, p. 2-24) to ensure that the EIS did not underestimate potential environmental impacts and to accommodate the greatest range of potential future actions.

DOE has established parameters for the range of potential repository operating modes and has identified these parameters and their ranges in Table 2-2. These operating modes provide the basis for evaluation of the environmental impacts described in Chapter 4. The key to ensuring that the range of potential impacts evaluated fully encompasses the impacts that could occur under any reasonable repository mode of operation requires a basic understanding of how the particular impacts relate to the various parameters, particularly those parameters that could be varied to achieve lower-temperature operation.

As shown in the Draft EIS and the Supplement to the Draft EIS, the short-term impacts (preclosure) would increase with the size of the repository emplacement area and surface facilities. The smallest repository and surface facilities are associated with the higher-temperature repository operating mode and therefore would result in the lowest short-term environmental impacts. As detailed in Section 2.1.1.2.2, the lower-temperature repository operating mode would be achieved by varying several of the design parameters independently or in combination, for differing effects. Design parameters include waste package loading, repository ventilation duration, and waste package spacing. In the analyses, DOE maximized each of these parameters in turn, and assumed reasonably conservative values for the other dependent parameters to evaluate the full range of potential environmental impacts. As an example, DOE considered a repository with the largest waste package spacing (6.4 meters), with and without the use of surface aging. The result was the largest repository emplacement area and surface facilities and therefore the highest potential impacts for some *environmental resource areas* (for example, land disturbance, nonradiological air quality, and water use). Conversely, when DOE assumed the long postemplacement ventilation period (up to 300 years), with and without the surface aging facility, the result was a repository that would be open for a longer period with higher potential for impacts to workers and release of naturally occurring radon from the open repository to the offsite public. DOE evaluated the reasonable combinations of these variable design parameters to establish the range of impacts reported in Chapter 4 and summarized in Section 2.4.

2.1.1.2.1 *Higher-Temperature Repository Operating Mode*

The higher-temperature repository operating mode would ensure that a portion of the rock between the drifts would have maximum temperatures below the boiling point of water [96°C (205°F)] (DIRS 153849-DOE 2001, Section 2.1.2) at the elevation of the emplacement horizon (see Figure 2-6). This would allow any water mobilized by the higher-temperature conditions in the drifts to drain between the drifts. The development of a localized boiling region around each emplacement drift, rather than a single boiling region encompassing all the emplacement drifts, would ensure that very little water would be able to accumulate above any emplacement drift. This would substantially decrease the likelihood of water penetrating the emplacement drifts by means of fast paths such as fractures. The higher-temperature operating mode is based on this heat management criterion to keep boiling temperatures from spreading

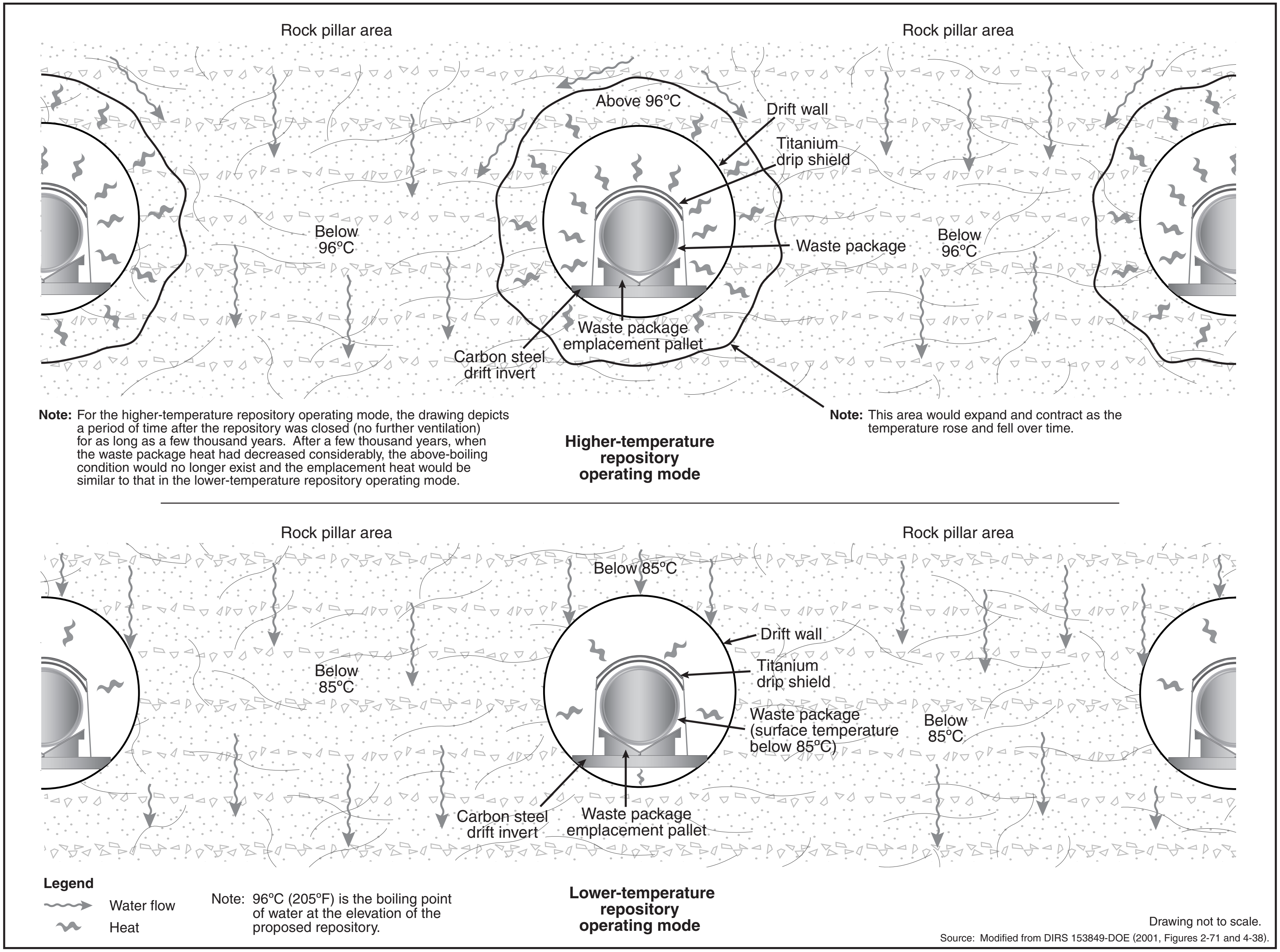


Figure 2-6. Artist's conception of water flow around emplacements for higher- and lower-temperature repository operating modes.

all the way through the rock between drifts after closure, while allowing repository closure as early as 50 years after the start of emplacement.

2.1.1.2.2 *Lower-Temperature Repository Operating Mode*

DOE could operate the repository in a lower-temperature mode by varying certain operational parameters. The lower-temperature operating mode range includes conditions under which the drift rock wall temperatures would be below the boiling point of water [96ºC (205ºF)] at the elevation of the repository, as well as conditions under which waste package average surface temperatures would not exceed 85ºC (185ºF) (see Figure 2-6).

DOE is considering the lower-temperature operating mode to reduce some of the uncertainties associated with assessing long-term repository performance. Lower temperatures might have less effect on rock properties and geochemistry, thereby reducing the complexities in modeling thermal effects. This, in turn, could reduce uncertainties in assessments of future repository performance. Lower in-drift temperatures could also reduce the potential for waste package corrosion.

The primary variables governing a lower waste package surface temperature and the thermal response of the surrounding rock would be the heat generation rate of the waste packages, the linear spacing of the waste packages in the emplacement drifts, and the rate and duration of ventilation after waste package emplacement in the drifts. Operational parameters that DOE could use (independently or in combination) to control repository temperatures (waste package, drift wall, and the overall repository) include (1) varying the waste package *thermal loading* to control the thermal output, (2) varying the duration of the preclosure ventilation period with 15-cubic-meter (530-cubic-foot)-per-second average drift ventilation, and (3) varying the distances between waste packages in the emplacement drifts (DIRS 153849-DOE 2001, Section 2.1.4). The operational parameters would work in combination to control the maximum waste package surface temperature and, thus, the heat transferred to the emplacement drift walls. DOE could use a combination of the three to maximize repository operational efficiency and achieve thermal objectives, as described below.

- *Waste Package Thermal Loading (including surface aging).* Commercial spent nuclear fuel would be the major contributor of heat in the repository. It would have a wide range of thermal outputs. The thermal output of the waste packages could be reduced, however, by varying waste package loading. Waste package thermal loading could be varied by (1) placing low-heat-output (older) fuel with high-heat-output (younger) fuel in the same waste package (fuel *blending*), (2) limiting the number of spent nuclear fuel assemblies to less than the waste package design capacity (derating), (3) using smaller waste packages, or (4) placing younger fuel in a surface aging area to allow its heat output to dissipate so it could meet thermal goals for later emplacement. Section 2.1.2.1.1.2 describes the fuel blending process further. Reducing the thermal output of the waste packages through any of these means would achieve lower waste package and drift wall temperatures. DOE would consider aging as much as two-thirds of the commercial spent nuclear fuel (DIRS 152007-Mattsson 2000, p. 2) during a 50-year period. Aging would require an extended emplacement period.

- *Drift Ventilation Duration.* During repository operations, forced-air (active) or natural (passive) ventilation of the loaded drifts would remove an appreciable part of the heat generated by the waste packages. DOE could reduce the amount of heat delivered to, and thus the maximum temperatures in, the host rock by extending the drift ventilation period with either active or passive ventilation. This could require an extended ventilation period of as long as 300 years after final emplacement to ensure that postclosure temperatures (waste package surface and drift wall) remained below specified goals (DIRS 153849-DOE 2001, Section 2.1.5.2, Table 2-2).

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- *Distance Between Waste Packages.* The distance between waste packages in emplacement drifts is another operational variable that DOE could use to manage the thermal response of the repository. With waste packages spaced farther apart, the linear thermal load in each drift would decrease, delivering less heat per unit length of the emplacement drift. Implementing an increase in average waste package spacing would require more emplacement drifts and potentially additional subsurface *infrastructure* than the higher-temperature repository operating mode. Under the lower-temperature repository operating mode, waste package spacing could vary from 0.1 meter (0.33 foot) (DIRS 153849-DOE 2001, Section 2.1.2.2) to 6.4 meters (21 feet) (DIRS 152003-McKenzie 2000, Option 1, p. 2).

These three operational parameters are interrelated; that is, they would work together to achieve the desired result. For example, a combination of 2.1-meter (6.9-foot) waste package spacing, surface aging of commercial spent nuclear fuel, and 125 years of forced-air ventilation (from the start of emplacement) would be adequate to achieve the repository lower-temperature thermal objectives. Another example would be a combination of 2-meter (6.6-foot) waste package spacing, no surface aging, and 75 years of forced-air ventilation (from the start of emplacement) followed by 250 years of *natural ventilation* (DIRS 153849-DOE 2001, Section 2.1.5.2, Table 2-2).

2.1.1.3 National Transportation Scenarios

The national transportation scenarios evaluated in this EIS encompass the transportation options or modes (legal-weight truck and rail) that are practical for DOE to use to ship spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site. DOE would use both legal-weight truck and rail transportation, and would determine the number of shipments by either mode as part of future transportation planning efforts. Therefore, the EIS evaluates two national transportation scenarios (mostly legal-weight truck and mostly rail) that cover the possible range of transportation impacts to human health and the environment.

TERMS ASSOCIATED WITH TRANSPORTATION

Legal-weight trucks have a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), which is the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be in compliance with Federal and state regulations.

An **intermodal transfer station** is a facility for transferring freight from one transportation mode to another (for example, from railcar to truck). In this EIS, intermodal transfer station refers to a facility DOE would use to transfer rail shipping casks containing spent nuclear fuel or high-level radioactive waste from railcars to heavy-haul trucks, and to transfer empty rail shipping casks from heavy-haul trucks to railcars.

Heavy-haul trucks are overweight, overdimension vehicles that must have permits from state highway authorities to use public highways. In this EIS, heavy-haul trucks refers to vehicles DOE would use on public highways to move spent nuclear fuel or high-level radioactive waste shipping casks designed for a railcar.

2.1.1.4 Nevada Transportation Scenarios and Rail and Intermodal Implementing Alternatives

The transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository would affect the states through which the shipments would travel, including Nevada. However, to highlight the impacts that could occur in Nevada, DOE has chosen to discuss them separately. DOE is looking at three transportation scenarios for Nevada. These scenarios include legal-weight truck and rail, which are the same as the national scenarios but highlight the Nevada portion of the transportation, and heavy-haul truck. The heavy-haul truck scenario includes the construction of an intermodal transfer station with associated highway improvements for heavy-haul trucks in the State. DOE has identified five potential rail corridors leading to Yucca Mountain and three potential intermodal transfer station locations with five associated potential highway routes for heavy-haul trucks. Section 2.1.3.3 describes these implementing alternatives.

2.1.1.5 Continuing Investigation of Design Options

As noted, this EIS describes and evaluates the flexible design concept for the repository and current plans for repository construction, operation and monitoring, and closure (see Section 2.1.2). DOE continues to investigate design options for possible incorporation in the final repository design; Appendix E identifies design features that DOE is considering for the final design (for example, specific design and operational considerations regarding natural ventilation and its duration; consideration of indefinite ventilation period; modular construction of repository facilities; whether to handle commercial spent nuclear fuel using a pool with water or a dry transfer system; and site access road construction). The criteria for selecting these design options are related to improving or reducing uncertainties in repository performance (the potential to provide containment and isolation of radionuclides) and operation (for example, worker and operational safety, ease of operation).

DOE has assessed each of the design options still being considered for the expected change it would have on short- and long-term environmental impacts and has compared these impacts to the potential impacts determined for the packaging, operating mode, and transportation scenarios evaluated in the EIS. This assessment, which is described in Appendix E, found that the changes in environmental impacts for the design options would be relatively minor in relation to the potential impacts evaluated in this EIS. Therefore, DOE has concluded that the analytical scenarios and implementing alternatives evaluated in this EIS provide a representative range of potential environmental impacts the Proposed Action could cause. Chapter 9 discusses mitigation from design options that could be beneficial in reducing impacts associated with repository performance or operation.

2.1.2 REPOSITORY FACILITIES AND OPERATIONS

This section describes proposed repository surface and subsurface facilities and operations (Sections 2.1.2.1 and 2.1.2.2), the performance confirmation program (Section 2.1.2.3), and repository closure (Section 2.1.2.4) . The description is based on the Science and Engineering Report (DIRS 153849-DOE 2001, all) and other engineering data files (DIRS 104508-CRWMS M&O 1999, all; DIRS 104523-CRWMS M&O 1999, all; DIRS 102030-CRWMS M&O 1999, all) unless otherwise noted. The following paragraphs contain an overview of the repository facilities and operations and the sequence of planned repository construction, operation and monitoring, and closure. DOE would design the repository based on the extensive information collected during the Yucca Mountain site characterization activities. These activities are summarized in semiannual site characterization reports. [See the semiannual Site Characterization Progress Reports that the Department prepares in accordance with Section 113(b)(3) of the NWPA (for example, DIRS 155982-DOE 2001, all).] The facilities used for site characterization activities at Yucca Mountain would be incorporated in the repository design to the extent practicable. (See Chapter 3, Section 3.1, for additional information on existing facilities at Yucca Mountain developed during site characterization activities.)

DOE would construct surface facilities at the repository site to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement. In addition, surface facilities would support the construction of subsurface facilities. These facilities include the following primary surface operations areas:

- North Portal Operations Area – Receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement
- South Portal Development Area – Support the construction of subsurface facilities
- Ventilation Shaft Operations Area – Supply air to and exhaust air from the subsurface facilities

Figure 2-7 is an aerial photograph of the Yucca Mountain site showing the locations of these surface facilities. The spent nuclear fuel and high-level radioactive waste would be handled remotely with workers shielded from *exposure* to radiation using design and operations practices in use at licensed nuclear facilities to the maximum extent practicable. The repository operations areas and supporting areas, utilities, roads, etc., would require the active use of as much as 6 square kilometers (1,500 acres) of land. Of this total area, about 1.5 square kilometers (370 acres) have been disturbed by previous activities.

Figure 2-8 shows the subsurface layout of the repository, which would consist of drifts (tunnels) and vertical ventilation shafts that DOE would excavate in the mountain. Along with the main drifts, gently sloping ramps from the surface to the subsurface facilities would move workers, equipment, and waste packages. Waste packages of spent nuclear fuel and high-level radioactive waste would be placed in the emplacement drifts. The ventilation systems would move air for workers and would cool the repository.

The following paragraphs contain an overview of the sequence of repository construction, operation and monitoring, and closure. Figure 2-9 shows the timing assumed for analysis, site recommendation, site designation, licensing review, construction, operation and monitoring, and closure of the proposed repository at Yucca Mountain. If the Yucca Mountain site was recommended for development as a repository, DOE would continue performance confirmation activities to support a License Application to the Nuclear Regulatory Commission in accordance with the NWPA. Performance confirmation activities after Site Recommendation and before the construction of performance confirmation drifts could be similar to activities performed during site characterization. These activities could require surface excavations and borings, subsurface excavations and borings, and in-place testing of rock characteristics.

The construction of repository facilities for the handling of spent nuclear fuel and high-level radioactive waste would begin after the receipt of construction authorization from the Nuclear Regulatory Commission. DOE assumed that construction would begin in 2005. The repository surface facilities, the main drifts, ventilation system, and initial emplacement drifts would be built in approximately 5 years, from 2005 to 2010 (DIRS 153849-DOE 2001, Section 2.3.5.1.1).

Repository operations would begin after DOE received a license amendment from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For analytical purposes, DOE assumed that the receipt and emplacement of these materials would begin in 2010 and would occur over a 24-year period, unless DOE used aging to implement the lower-temperature repository operating mode. With aging, the emplacement period would be 50 years. DOE also assumed that material receipt would occur at a rate of approximately 3,000 MTHM per year. The emplacement rates discussed here are estimated for analytical purposes only, and would need to be refined should a repository be constructed.

The construction of emplacement drifts would continue for 22 years during emplacement, or would continue until near the end of aging if aging was used to achieve the lower-temperature repository operating mode. The repository design would enable simultaneous construction and emplacement

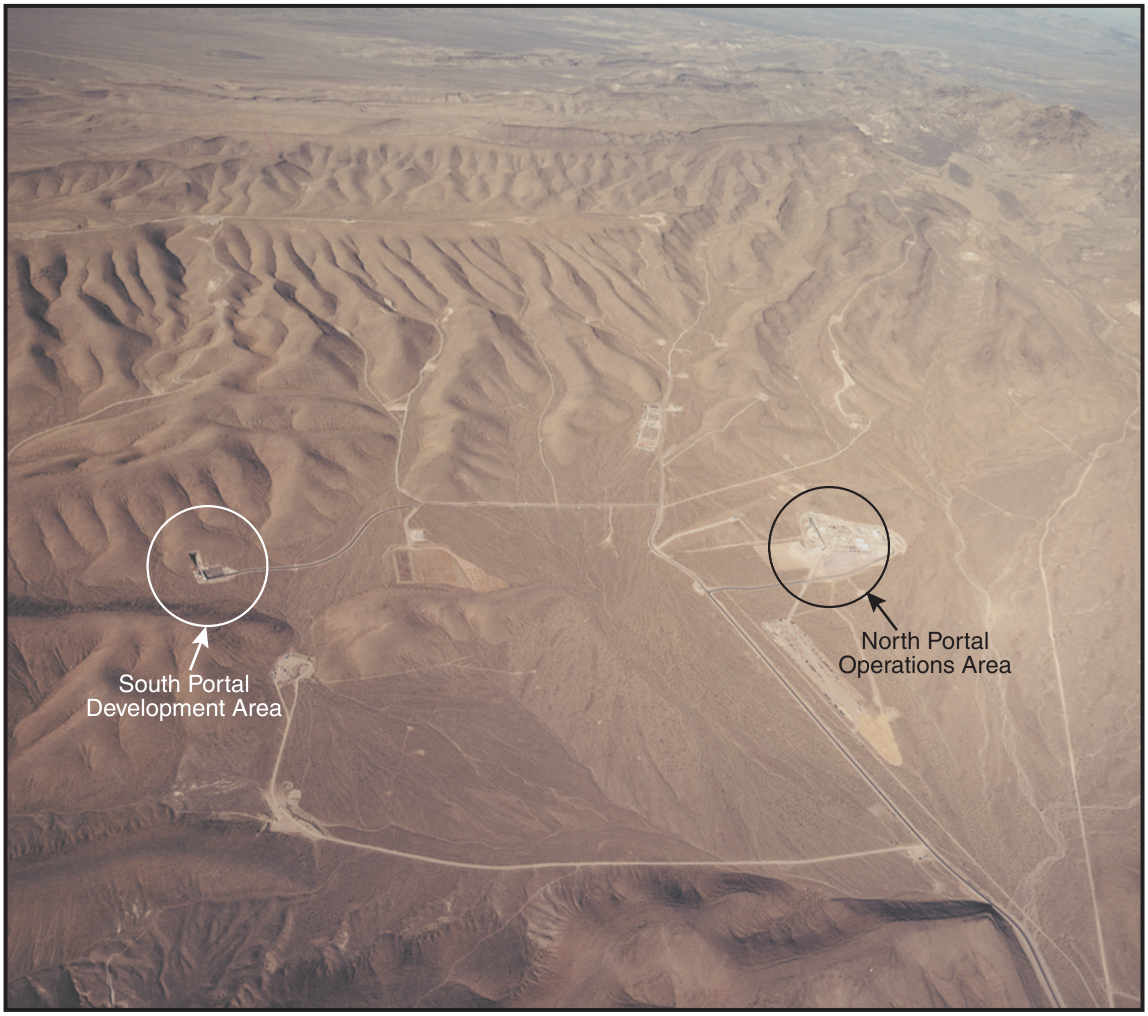
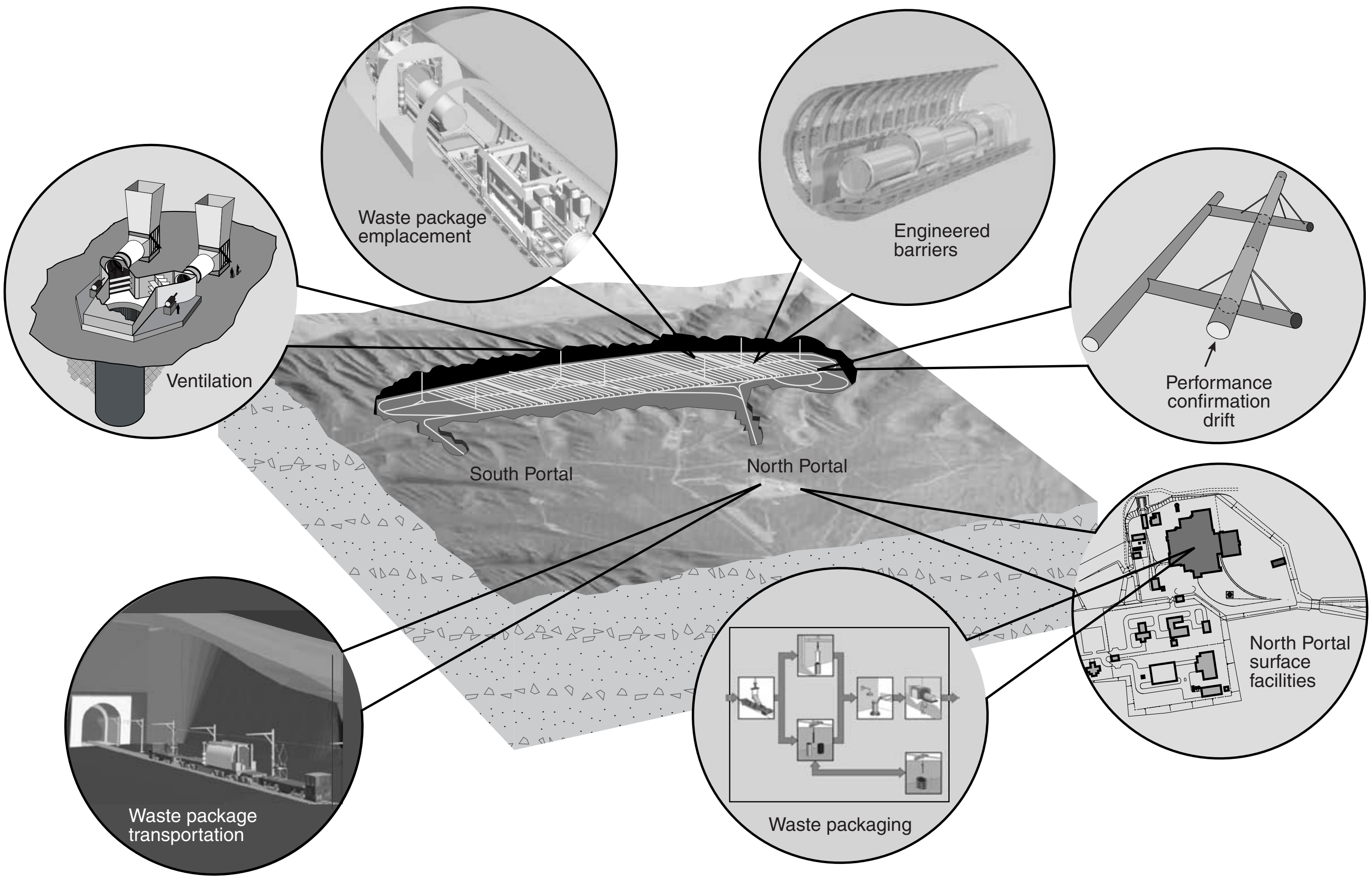


Figure 2-7. Surface facilities at the proposed Yucca Mountain Repository.

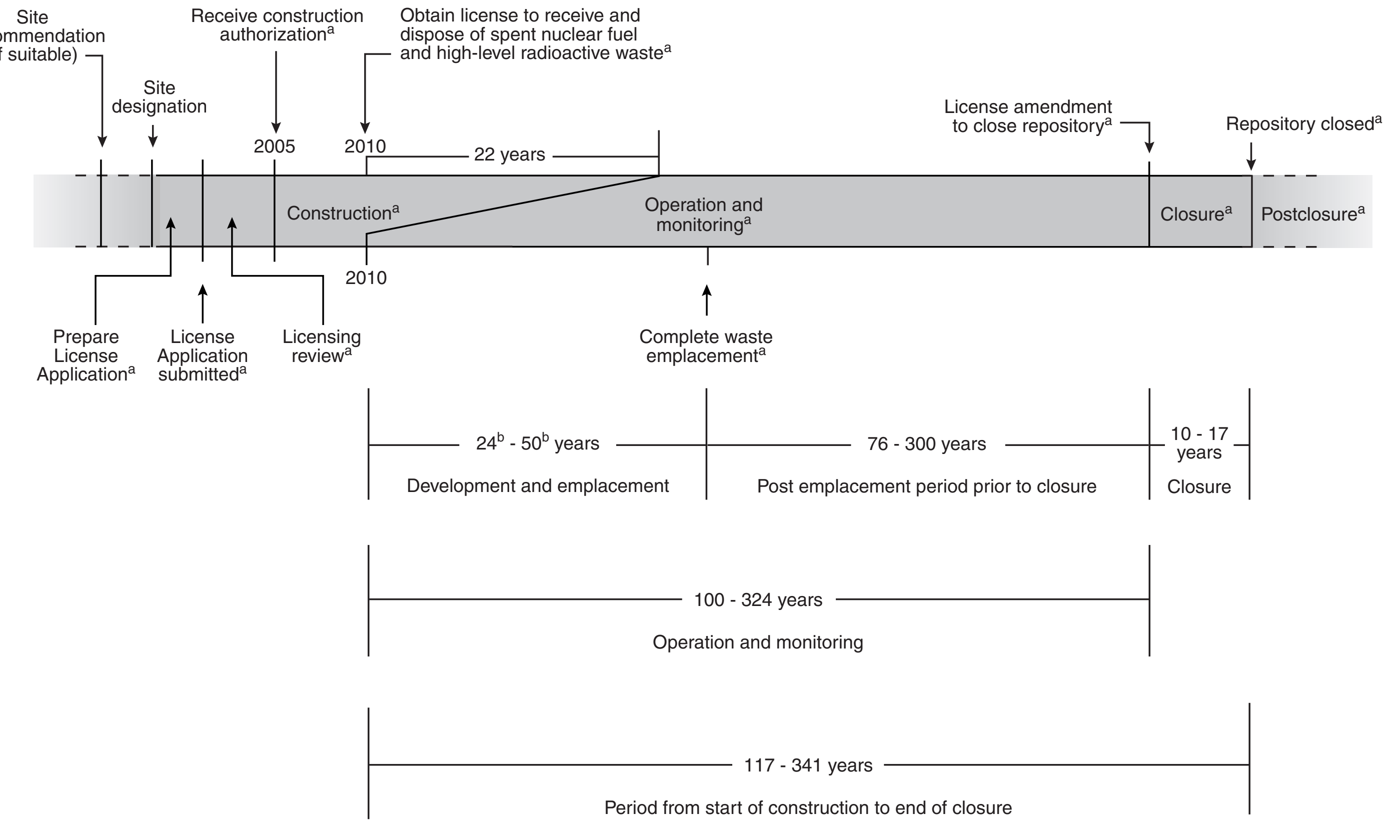
operations, and would physically separate activities on the construction or development side of the repository from activities on the emplacement side. This would provide protection of workers and appropriate ventilation of the emplaced waste.

Monitoring and maintenance activities would start with the first emplacement of waste packages and would continue through repository closure. After the completion of emplacement, DOE would maintain those repository facilities, including the ventilation system and utilities (air, water, electric power) that would enable continued monitoring and inspection of the emplaced waste packages, continued investigations in support of estimates of long-term repository performance, and the *retrieval* of waste packages if necessary. Immediately after the completion of emplacement, DOE would decontaminate and close the surface facilities that handled nuclear materials to eliminate any potential radioactive material release and would place surface facilities in a standby condition. That is, they could be reactivated if necessary. DOE would maintain an area in the Waste Handling Building for the possible testing of waste packages as a quality assurance contingency in the performance confirmation program. Future generations would decide whether to continue to maintain the repository in an open, monitored condition or to close it. To ensure flexibility to future decisionmakers, the EIS analyzed the repository with the capability for closure as early as 50 years or as late as 324 years after the start of emplacement based on



Source: Modified from DIRS 153849-DOE (2001, Figure 2-1).

Figure 2-8. Artist's conception of proposed repository facilities.



a. If Yucca Mountain is approved.
b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Note: See Table 2-2 for range of emplacement, preclosure ventilation, and closure durations.

Sources: Modified from DIRS 104523-CRWMS M&O (1999, Figure 1.5-1, p.1-3).

Figure 2-9. Monitored geologic repository range of milestones used for analysis.

example scenarios in the Science and Engineering Report (DIRS 153849-DOE 2001, Section 2.1.5). As stated in the Science and Engineering Report, for the higher-temperature repository operating mode, the start of closure could occur as early as 50 years after initial emplacement. The EIS analysis of the higher-temperature operating mode assumes that closure would begin 100 years after the start (76 years after the completion) of emplacement to facilitate comparisons. The lower-temperature repository operating mode would require a longer period of ventilation. This EIS evaluates closure of the repository in the lower-temperature mode after forced ventilation for as many as 324 years after the start of emplacement.

The performance confirmation program would continue some of the activities initiated during site characterization until repository closure, including various types of tests, experiments, and analytical procedures. DOE would conduct performance confirmation activities to further evaluate the accuracy and adequacy of the information used to demonstrate compliance that the repository would meet performance objectives.

Throughout the construction, operation, monitoring and maintenance, and closure periods, the repository would remain under effective institutional control. Under institutional control, the repository would be maintained to ensure that workers and the public were protected adequately in compliance with applicable Federal regulations and the requirements in DOE Order 5400.5 "Radiation Protection of the Public and the Environment."

Repository closure would occur after DOE received a license amendment from the Nuclear Regulatory Commission. Closure would take about 10 years for the higher-temperature repository operating mode (DIRS 150941-CRWMS M&O 2000, p. 6-22), and from 11 to 17 years for the lower-temperature repository operating mode. Closure of the repository facilities would include emplacing the drip shields, closing the subsurface facilities, completely decontaminating and decommissioning the surface facilities, reclaiming the disturbed surface areas, and establishing long-term institutional controls, including land records and warning systems to limit or prevent intentional or unintentional activity in and around the closed repository. DOE would establish a postclosure monitoring program, as required by Section 801(c) of the Energy Policy Act of 1992 (Public Law 102-486, 106 Stat. 2776); the Nuclear Regulatory Commission has regulations (10 CFR Part 63) addressing postclosure monitoring.

2.1.2.1 Repository Surface Facilities and Operations

Surface facilities at the repository site would receive, prepare, stage, and package spent nuclear fuel and high-level radioactive waste for subsurface emplacement. In addition, they would support the construction of the subsurface facilities. DOE would upgrade some surface facilities built for site characterization, but most would be new. Most facilities would be in three areas—the North Portal Operations Area, the South Portal Development Area, and the Ventilation Shaft Operations Areas. Facilities to support waste emplacement would be concentrated near the North Portal, and facilities to support subsurface facility development would be concentrated near the South Portal. The following sections describe these areas in more detail. In addition, Section 2.1.2.1.4 describes support facilities and utilities.

2.1.2.1.1 *North Portal Operations Area*

This area, shown in Figure 2-10, would be the largest of the primary operations areas, covering about 0.6 square kilometer (150 acres) (DIRS 104508-CRWMS M&O 1999, Section 4.2.3.1) at the North Portal. It would include two areas: a *Radiologically Controlled Area* for receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste prior to emplacement, and a Balance of Plant Area for support services (such as administration, training, and maintenance). The Radiologically Controlled Area would be monitored to ensure adequate safeguards and security for radioactive materials. The two

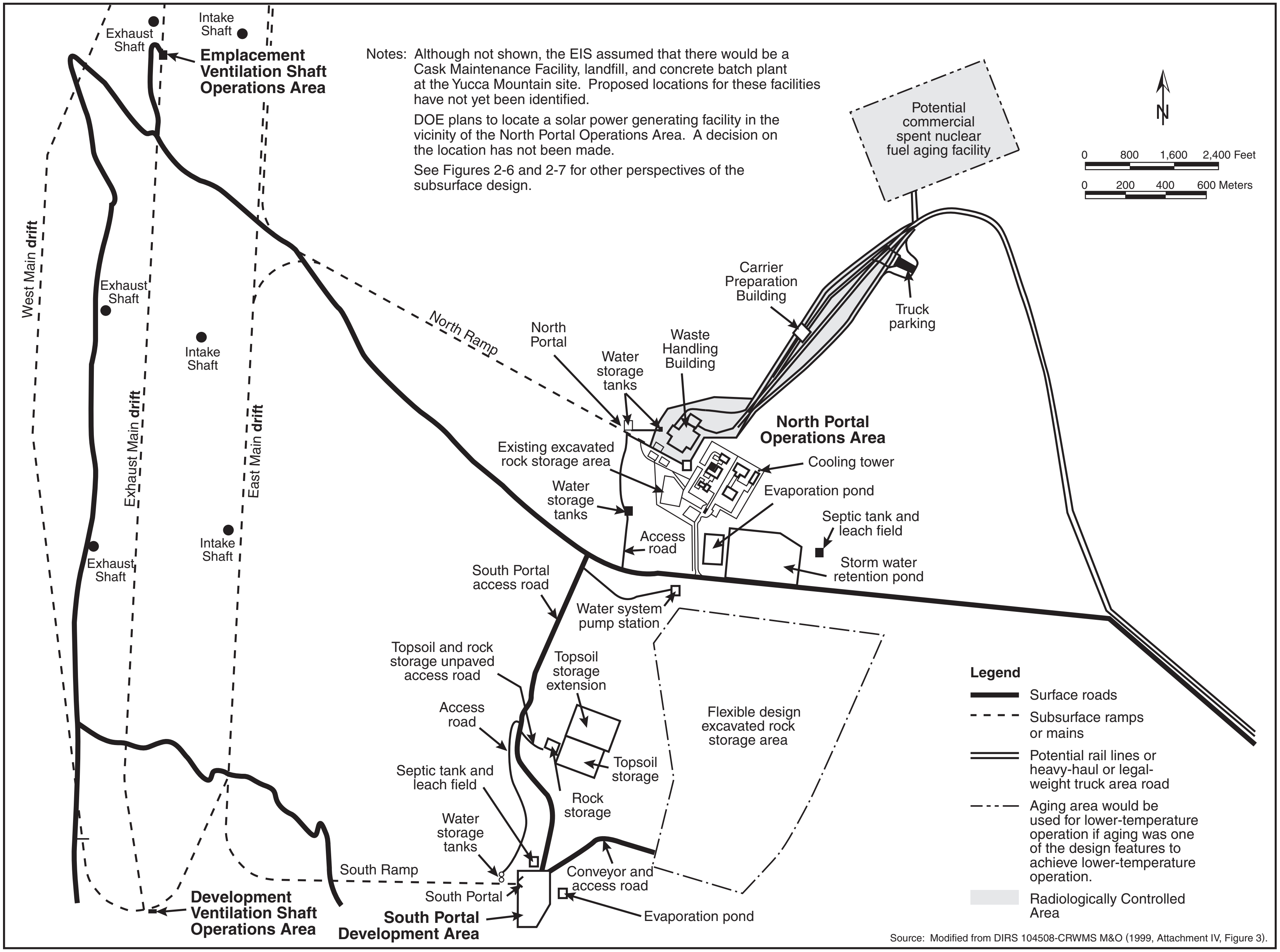


Figure 2-10. Potential repository surface facilities site plan.

principal facilities in the Radiologically Controlled Area for handling spent nuclear fuel and high-level radioactive waste would be the Carrier Preparation Building and the Waste Handling Building. If DOE uses aging to achieve lower-temperature operation, the commercial nuclear fuel aging area would also be included within the Radiologically Controlled Area. Other support facilities in the North Portal Operations Area would include basic facilities for personnel support, warehousing, security, parking and visitors center, and transportation (motor pool). A concrete plant for fabricating and curing precast components and supplying concrete for *in-situ* placement would be near the North Portal Operations Area.

2.1.2.1.1.1 Waste Handling. When a legal-weight or heavy-haul truck or a railcar (depending on the transportation mode) hauling a *cask* containing spent nuclear fuel or high-level radioactive waste arrived at the repository site, it would move through the security check into the Radiologically Controlled Area parking area or to the Carrier Preparation Building. Operations in the Carrier Preparation Building would include performing inspections of the vehicle and cask, removing barriers from the vehicle that protected personnel during shipment, and removing *impact limiters* from the cask. The vehicle would then move to the Waste Handling Building for unloading.

At the Waste Handling Building carrier bay, the carrier/cask handling system would lift the transportation cask to a vertical position and place it on a cask transfer cart. Depending on the cask's contents, the cart would move to one of two transfer systems. Casks that contain disposable canisters (for example, DOE canisters that would not be opened but transferred, as is, directly into a *disposal container*) would go to the canister transfer system. Casks that contain commercial spent nuclear fuel in dual-purpose canisters or individual *fuel assemblies* would go to the assembly transfer system. Figure 2-11 is a flow diagram of Waste Handling Building operations.

The Waste Handling Building would have one canister transfer line that moves the disposable canisters through the building to prepare the waste for emplacement in the repository. The system would move arriving casks through an *air lock* on a transfer cart into a cask preparation area. Once a cask arrived inside the cask preparation area, workers would use remotely operated equipment to vent and sample gases from the cask, remove the lid bolts, and open the cask. An overhead crane would move the cask to a transfer cart, which would take the cask to a shielded transfer area. Inside the transfer area, machines would remove the canister from the cask. The canister could go directly into a disposal container for repository emplacement, or to a holding rack for later placement in a disposal container. Another transfer cart would move loaded disposal containers to the disposal container handling system. A transfer cart would move the empty transportation casks back to the cask *decontamination* area, where they would be surveyed and decontaminated, if required, before return shipment. From the decontamination area, casks would be moved to the carrier/cask handling system, which would place them back on a transporter. The empty cask and cask transporter would return to the Carrier Preparation Building to be readied for offsite shipment.

The Waste Handling Building would also have two assembly transfer lines. Each line would operate independently to handle waste throughput and support maintenance operations. The assembly transfer process would begin by moving the cask on a transfer cart through the air lock into the cask preparation area. Once inside the cask preparation area, workers would use remotely operated equipment to inspect, vent, and cool the cask and remove the cask lid bolts. A large overhead crane would lift the casks and place them in a cask unloading pool, where fuel-handling machines would open the casks and unload the fuel assemblies. If the cask contained dual-purpose canisters, they would be removed and placed in an overpack, where the top of the canister would be cut off. The system would move the empty casks and dual-purpose containers back out through the cask decontamination area. The fuel-handling machines would transfer the fuel assemblies, one at a time, to a holding pool, where they would be placed in assembly baskets. A transfer cart would move the baskets containing the fuel assemblies underwater from the assembly holding pool through a transfer canal to a fuel-blending inventory pool. (See

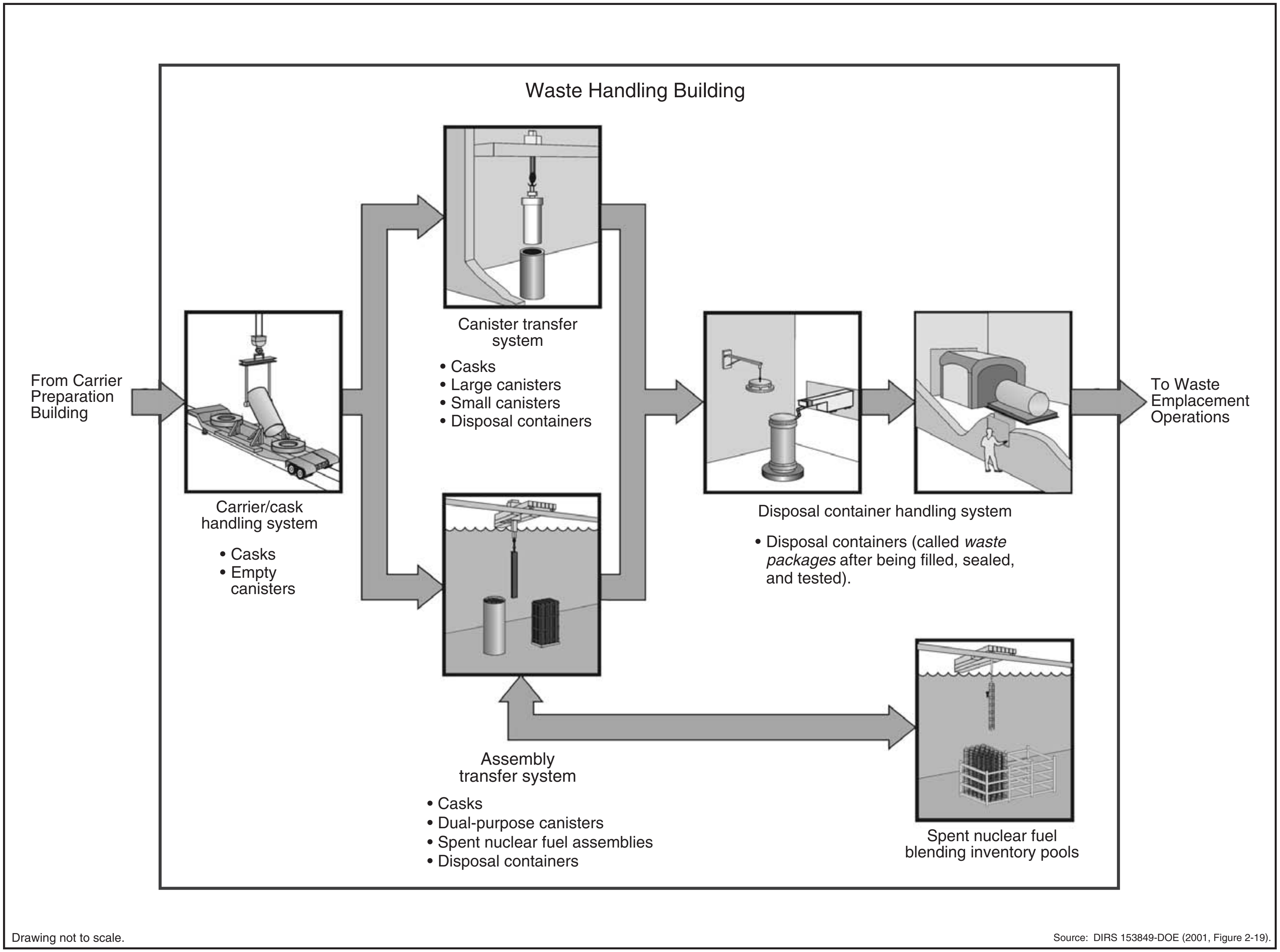


Figure 2-11. Key components of Waste Handling Building operations.

Section 2.1.2.1.1.2 for further information on the processes for blending, use of small waste packages, and aging to meet the flexible design linear thermal load criteria.) When a fuel assembly was selected from the fuel inventory pool for packaging, a transfer cart would move it underwater back through the fuel blending pool to an inclined transfer canal and onto a cart that connects to the assembly drying area.

After fuel assemblies arrived at the assembly drying area, a fuel-handling machine would transfer them into one of two drying vessels. After drying, the system would retrieve the assemblies and transfer them, one at a time, to a disposal container. The empty assembly baskets would be returned to the pool area for reuse. After installation of the sealing device and the inner lid, the system would then evacuate the disposal container internal cavity and fill it with nitrogen gas to exclude oxygen and prevent corrosion from the inside of the waste package. Finally, the transfer cart would transfer the container to the lid welding and inspection area.

The disposal container handling system would receive loaded disposal containers from both the canister transfer system and the assembly transfer system. Each disposal container would again be evacuated and filled with helium, after which the container's lids would be welded and the welds inspected. If the welds meet inspection criteria, the sealed disposal container would be reclassified as a waste package. A crane would transfer the waste package to the transporter loading area, where it would be decontaminated and placed on a pallet, then on a transporter for emplacement in the subsurface repository.

For more details on waste handling, see Section 2.2.4.2 of the Science and Engineering Report (DIRS 153849-DOE 2001).

2.1.2.1.1.2 Approach to Fuel Blending. Spent nuclear fuel and high-level radioactive waste arriving at the repository would be in solid form, but in a variety of types and sizes. Hence, the materials would arrive in a variety of transportation casks, all certified for use by the Nuclear Regulatory Commission. Commercial spent nuclear fuel would arrive as either individual fuel assemblies placed directly into transportation casks, or in dual-purpose canisters in transportation casks that would have to be opened to remove the fuel assemblies. DOE spent nuclear fuel and high-level radioactive waste would arrive in disposable canisters (that is, canisters that would not be opened, but would be transferred directly into a disposal container). Because of the variety of waste forms to be disposed of, about 10 different designs for disposal containers (called waste packages after being loaded, sealed, and certified) would be needed (DIRS 153849-DOE 2001, Section 2.2.1).

The radioactive decay process generates heat. The concentrations of particular isotopes would vary among the different waste forms, and among different fuel assembles in the same type of waste form, so different waste packages would generate different amounts of heat. Because the repository would have established temperature limits, DOE would establish a maximum heat output for all waste packages. For the repository, the maximum heat output would be 11.8 kilowatts per waste package (DIRS 153849-DOE 2001, Section 2.2.1).

The limit on heat output from individual waste packages would impose special considerations for operations and costs. The DOE strategy for controlling heat output would be to load waste packages that mixed low-heat-output spent nuclear fuel with high-heat-output spent nuclear fuel to balance total waste package heat output. This process, called *fuel blending* (DIRS 153849-DOE 2001, Section 2.2.1), would apply only to commercial spent nuclear fuel, which generates much more heat than DOE spent nuclear fuel or high-level radioactive waste (see Appendix A).

To manage heat output, DOE would hold some fuel assemblies in the fuel blending pool in the Waste Handling Building inventory until they generated less heat from radioactive decay or until additional low-heat-output fuel assemblies arrived for blending. The repository would be designed with a fuel blending inventory capacity of approximately 5,000 MTHM, or 12,000 spent nuclear fuel assemblies. By carefully planning and implementing a fuel-blending procedure, DOE could limit and optimize the heat output of the waste packages without increasing their number (DIRS 153849-DOE 2001, Section 2.2.1).

Potential Additional Assembly Transfer Lines in Waste Handling Building. If DOE were to use the smaller waste packages to achieve lower-temperature operation, there would be an increase in the number of assembly transfer lines from two to four. The number of associated hot cells, welding stations, and waste package transporter loading lines would also increase to accommodate the additional canister and waste package handling capacity needed to maintain an emplacement rate of 3,000 MTHM per year. The overall handling process would be the same as that described above.

Potential Commercial Spent Nuclear Fuel Aging Facility. If DOE were to use aging of commercial spent nuclear fuel to achieve the lower-temperature repository operating mode, the aging area would be north and east of the North Portal Operations Area (see Figure 2-10). The spent nuclear fuel aging facility would include access roads, aisles, security fences, and concrete pads to implement the aging process. This area and access to it from the Waste Handling Building would be appropriately restricted for radiation control.

With the use of aging, the handling of commercial spent nuclear fuel would be different than the approach described above because the 5,000-MTHM (12,000 assemblies) blending inventory pools would be unnecessary. Instead, DOE would use a small staging pool for fewer than 80 assemblies for handling processes that required a pool. DOE would replace the assembly transfer system with two dry handling lines, and would add a dry staging hot cell. Commercial spent nuclear fuel would be handled as described above, except it would be loaded into a canister at the surface facility. The canister would be loaded into a dry *storage cask* for movement to and placement on a pad in the aging facility for the duration of the aging period (emplacement with aging is assumed to require 50 years). A motorized or towed transporter, designed to support the aging process, would be used to move the dry storage canister to the aging facility. When the spent nuclear fuel had completed the aging process, it would be transferred from the aging facility to the Waste Handling Building to be placed in a waste package for emplacement as described above.

The Science and Engineering Report (DIRS 153849-DOE 2001), Section 2.1.5, Assessing the Performance of a Lower-Temperature Operating Mode, and Section 2.2, Repository Surface Facilities, provide further detail on the proposed repository higher- and lower-temperature operations. Section 2.2.1 of the Science and Engineering Report provides further discussion on fuel blending strategies and Section 2.2.2.2 provides a more detailed description of the waste handling operations and blending. The essential features for EIS analysis have been presented here.

2.1.2.1.1.3 Generation of Wastes. DOE would decontaminate empty canisters, shipping casks, and related components as required in the Waste Handling Building. After decontamination, the empty canisters and shipping casks would be loaded on truck or rail carriers, sent to the Carrier Preparation Building for processing, and shipped off the site.

Waste generated at the repository from the decontamination of canisters and shipping casks and from other repository housekeeping activities would be collected, processed, packaged, and staged in the Waste Treatment Building before being shipped off the site for disposal at permitted facilities. Waste minimization and pollution prevention measures would reduce the amount of *site-generated waste* requiring such management. For example, decontamination water could be treated and recycled to the extent practicable. Site-generated wastes would include low-level radioactive waste, *hazardous waste*, and *industrial solid waste*. Operations would not be likely, but that could occur, could produce small amounts of mixed wastes (wastes containing both radioactive and hazardous materials). The repository design would include provisions for collecting and storing mixed waste for offsite disposal.

The ventilation systems for the Waste Handling Building and the Waste Treatment Building would provide confinement of radioactive contamination by using pressure differentials to ensure that the air would flow from areas free of contamination to areas potentially contaminated to areas that are normally contaminated. The monitored exhaust air from both buildings would pass through high-efficiency particulate air filters before being released through a single exhaust stack.

2.1.2.1.2 *South Portal Development Area*

The South Portal Development Area would cover about 0.15 square kilometer (37 acres) immediately adjacent to the South Portal of the subsurface facility. The structures and equipment in this area, which would support the development of subsurface facilities, would include steel warehousing, and basic facilities for personnel support, maintenance, warehousing, material staging, security, and transportation. From this area, overland conveyors would transport excavated rock from the repository to the excavated rock storage area (see Figure 2-10).

2.1.2.1.3 *Ventilation Shaft Operations Areas*

The higher-temperature repository operating mode would require three emplacement intake *shafts* and one development intake shaft to support simultaneous development and emplacement activities (see Figure 2-12). Three exhaust shafts would support the full emplacement of 70,000 MTHM. The lower-temperature repository operating mode could require three to seven emplacement intake shafts, one development intake shaft, and five to nine exhaust shafts, depending on the repository layout (DIRS 152003-McKenzie 2000, Option 1, p. 3, and Option 2, p. 3). See Section 2.1.2.2.2 for more discussion of the overall ventilation of the repository and Table 2-2 for a comparative listing.

The Ventilation Shaft Operations Area would have separately developed areas of approximately 0.012 square kilometer (3 acres) each for the emplacement intake, development intake, and exhaust shafts. The total area required for ventilation shafts would range from 0.0085 square kilometer (21 acres) for the higher-temperature operating mode and 0.021 square kilometer (51 acres) for the larger lower-temperature operating mode repository. Each exhaust shaft would contain two 2,000-horsepower fans, with a combined capacity of 800 to 850 cubic meters per second (28,000 to 30,000 cubic feet per second). The ventilation system would be monitored for radioactivity and the air would be filtered as needed.

2.1.2.1.4 *Support Facilities and Utilities*

2.1.2.1.4.1 Storage of Excavated Rock. Repository support facilities and utilities would be on the surface in the general vicinity of the North Portal Operations Area and the South Portal Development Area (see Figure 2-10). The storage area for excavated rock would be the largest support area. The excavated rock storage area for the higher-temperature repository operating mode would be 0.9 square kilometer (220 acres) (DIRS 150941-CRWMS M&O 2000, Figure 6-1). The amount of excavated rock would increase under the lower-temperature repository operating mode as a result of increased waste package spacing. This rock would be stored in the excavated rock storage area, which could be as large as 1.4 square kilometers (347 acres) (DIRS 152003-McKenzie 2000, Option 1, p. 24). Table 2-2 lists the range of the amount of excavated rock for the repository operating modes considered in this Final EIS.

2.1.2.1.4.2 Wastewater and Stormwater Facilities. The repository site would have two evaporation ponds for industrial wastewater, one near the North Portal and one near the South Portal. Sources of industrial wastewater that would go into these ponds include dust suppression water returned to the surface from tunnel boring operations, blowdown from cooling-tower operations at the North Portal, and water from concrete mixing and cleanup. The industrial wastes would be normal operational affluents that would not contain radiological waste and would be processed according to industrial standards and regulations. In both ponds, heavy plastic liners would prevent water migration into the soil.

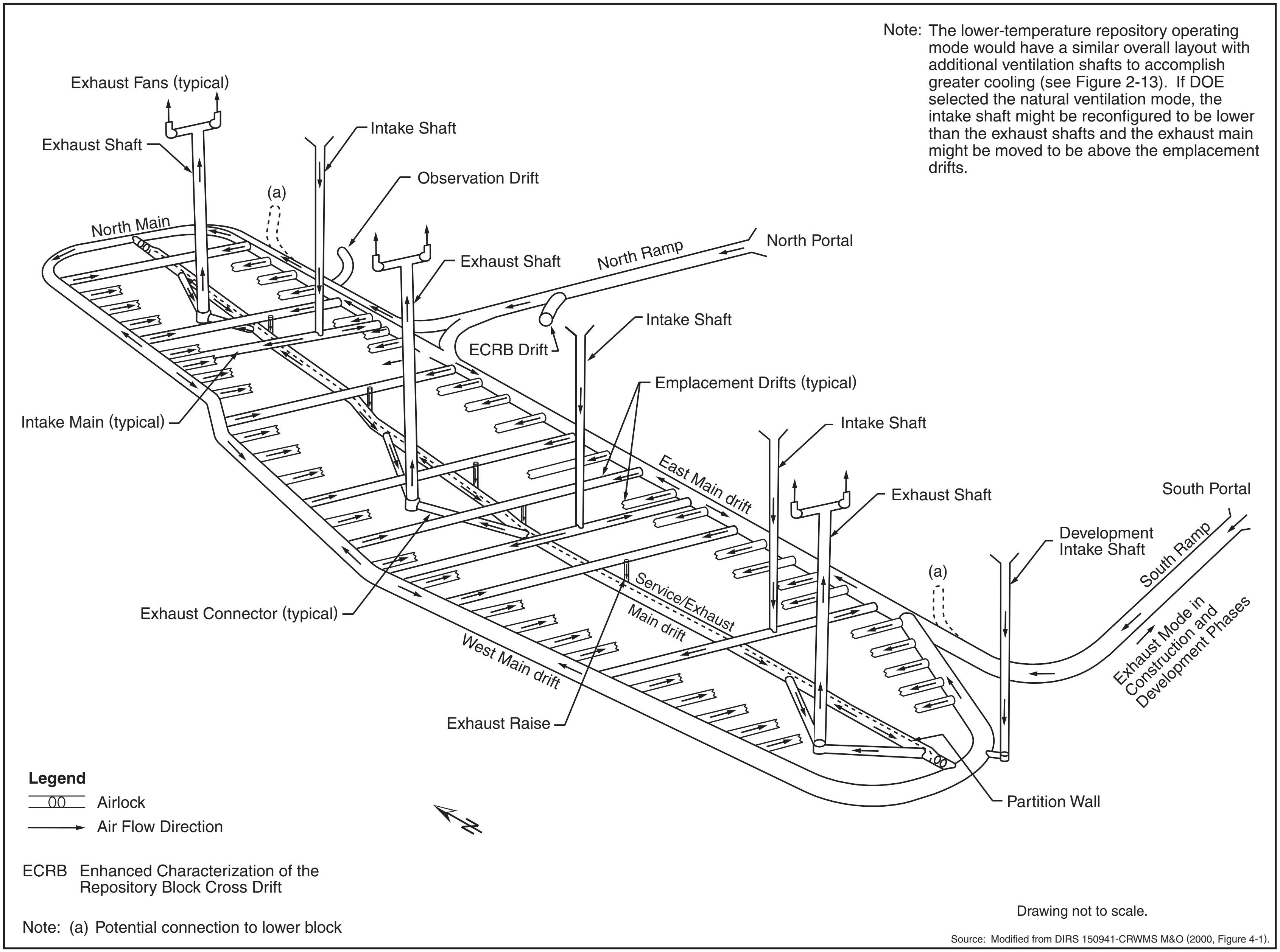


Figure 2-12. Higher-temperature repository operating mode preclosure ventilation air flow in primary block.

The North Portal pond would cover about 0.024 square kilometer (6 acres). The evaporation pond at the South Portal would be about 0.0024 square kilometer (0.6 acre). The North Portal Operations Area would also include an approximately 0.13-square-kilometer (32-acre) stormwater retention pond to control stormwater runoff from the area.

2.1.2.1.4.3 Solid Waste Disposal and Hazardous Waste Management. DOE would package hazardous waste and ship it off the site for treatment and disposal. The Department would develop an appropriately sized landfill [approximately 0.036 square kilometer (9 acres)] at the repository site for nonhazardous and nonradiological construction and *sanitary solid waste* and for similar waste generated during the operation and monitoring and closure phases. The South Portal Development Area would have a septic tank and leach field for the disposal of sanitary sewage. The North Portal Operations Area has an existing septic system that would be adequate for use during repository operations.

2.1.2.1.4.4 Electric Power. The repository would use the Nevada Test Site electric power distribution system, which would require upgrades to handle the demand for the various operational modes considered. At present, electric power at the Yucca Mountain site comes from that system. For the repository, electric power would be distributed throughout the surface and subsurface areas and to remote areas such as the Ventilation Shaft Operations Areas, construction areas, *environmental monitoring* stations, transportation lighting and safety systems, and water wells. To accommodate the expected electric power demand for the repository (estimated to be between 40 and 54 megawatts at peak demand), DOE would upgrade existing electrical transmission and distribution systems. Backup equipment and uninterruptible electric power would ensure personnel safety and operations requiring electric power continuity. Diesel generators and associated switchgear would provide the backup power capability.

In addition, DOE would use electricity from renewable energy sources at the repository (DIRS 153882-Griffith 2001, all). The repository design would include a solar power generating facility, which could produce as much as 3 megawatts of power, and would be a dual-purpose facility, serving as a demonstration of *photovoltaic* power generation and augmenting the overall repository electric power supply (as much as 7 percent). This facility would require about 0.16 square kilometer (40 acres), plus land for an access road and transmission line (DIRS 153882-Griffith 2001, p. 1). The system would be constructed in phases of 500 kilowatts starting in 2005 (DIRS 153882-Griffith 2001, pp. 1 and 6). It would be connected to the repository electric power distribution system. A typical solar power generating facility consists of solar cells (photovoltaic arrays) and support facilities. The solar power generating facility could be in the vicinity of the North Portal Operations Area.

2.1.2.1.4.5 Water Supply. DOE would continue to use existing wells about 5.6 kilometers (3.5 miles) southeast of the North Portal Operations Area to supply water for repository activities for both operating modes. These wells have supplied water for site characterization activities. DOE would seek the necessary authorization to continue withdrawing water from the wells for repository activities. Alternative water sources could include supplying water via truck and pipeline.

Water would be pumped to a booster pump station, then to storage tanks at the North Portal Operations Area and the South Portal Development Area. These elevated tanks would provide gravity-fed water to the distribution systems. At both portal areas, water would go to potable and nonpotable water systems; the nonpotable systems would provide water to fire protection systems, to the supplemental system that would supply deionized water to the fuel storage pools, and to the cooling tower for the heating, ventilation, and air conditioning system.

2.1.2.1.4.6 Fossil Fuel. Fuel supply systems would include fuel oil for a central heating (hot water) plant, which would consist of a main tank and a day tank. In addition, there would be fuel supply systems for fire water system tank heaters, for diesel-powered standby generators and air compressors, and for backup fire pumps. There would also be diesel fuel and gasoline to fuel vehicles during the construction, operation and monitoring, and closure of the repository. In addition, fossil-fuel powered vehicles would maintain the excavated rock storage area.

2.1.2.2 Repository Subsurface Facilities and Operations

DOE would construct the subsurface facilities of the repository and emplace the waste packages above the water table in a mass of volcanic rock (referred to as the *repository block*) known as the Topopah Spring Formation, which consists of *welded tuff* (see Chapter 3, Section 3.1.3.1). The specific area in this formation where DOE would build the repository emplacement drifts would satisfy several criteria: (1) to be in select portions of the Topopah Spring Formation that have desirable properties, (2) to avoid major faults for reasons related to both hydrology and *seismic* hazards (see Section 3.1.3.2), (3) to be at least 200 meters (660 feet) below the surface (DIRS 154554-BSC 2001, Section 4.2.1.2.9, p. 29), and (4) to be at least 160 meters (530 feet) above the present-day water table (DIRS 154554-BSC 2001, Section 4.2.1.2.4 p. 28).

The flexible design would use part or all of the layout shown in Figure 2-13. The smallest area that DOE would use is the shaded area that corresponds to the higher-temperature repository operating mode. DOE would use the full area shown for some of the possible lower-temperature repository operating modes (DIRS 153849-DOE 2001, Section 2.1.5.1).

The higher-temperature operating mode would utilize the upper (primary) block of the repository, using 4.7 square kilometers (1,150 acres) (DIRS 153849-DOE 2001, Section 2.3.1.1) (see Figure 2-13) and would require seven emplacement and development ventilation shafts. The lower-temperature repository operating mode could require as many as 17 ventilation shafts (see Table 2-2).

2.1.2.2.1 *Subsurface Facility Design and Construction*

The subsurface design would incorporate most of the drifts developed during the site characterization activities. Other areas would be excavated during the repository construction phase. Excavated openings would include gently sloping access ramps to enable rail-based movement of construction and waste package handling vehicles between the surface and subsurface, subsurface main drifts to enable the movement of construction and waste package handling vehicles, emplacement drifts for the placement of waste packages, exhaust mains to transfer air in the subsurface area, and ventilation shafts to transfer air between the surface and the subsurface. There would also be performance confirmation (observation) drifts for the placement of instrumentation to monitor emplaced waste packages (see Figure 2-13).

Access ramps connecting the surface and subsurface would be concrete-lined, 7.6-meter (25-foot)-diameter tunnels excavated by electric-powered tunnel boring machines (see Figure 2-14). Rail lines and an overhead trolley system would enable the movement of electric-powered construction and waste package handling vehicles. DOE developed the North and South Ramps, which would become part of the proposed repository, during site characterization. The North Ramp begins at the North Portal Operations Area on the surface (see Section 2.1.2.1.1) and extends through the subsurface to the edge of the repository area. It would support waste package emplacement operations. The South Ramp originates at the South Portal Development Area on the surface (see Section 2.1.2.1.2) and extends through the subsurface to the edge of the repository area. It would support subsurface construction and development activities.

The main drifts for the higher-temperature repository operating mode would include the East Main, the West Main, and the North Main. These drifts would be extended for the lower-temperature operating modes and additional main drifts would be excavated to provide access to other emplacement areas.

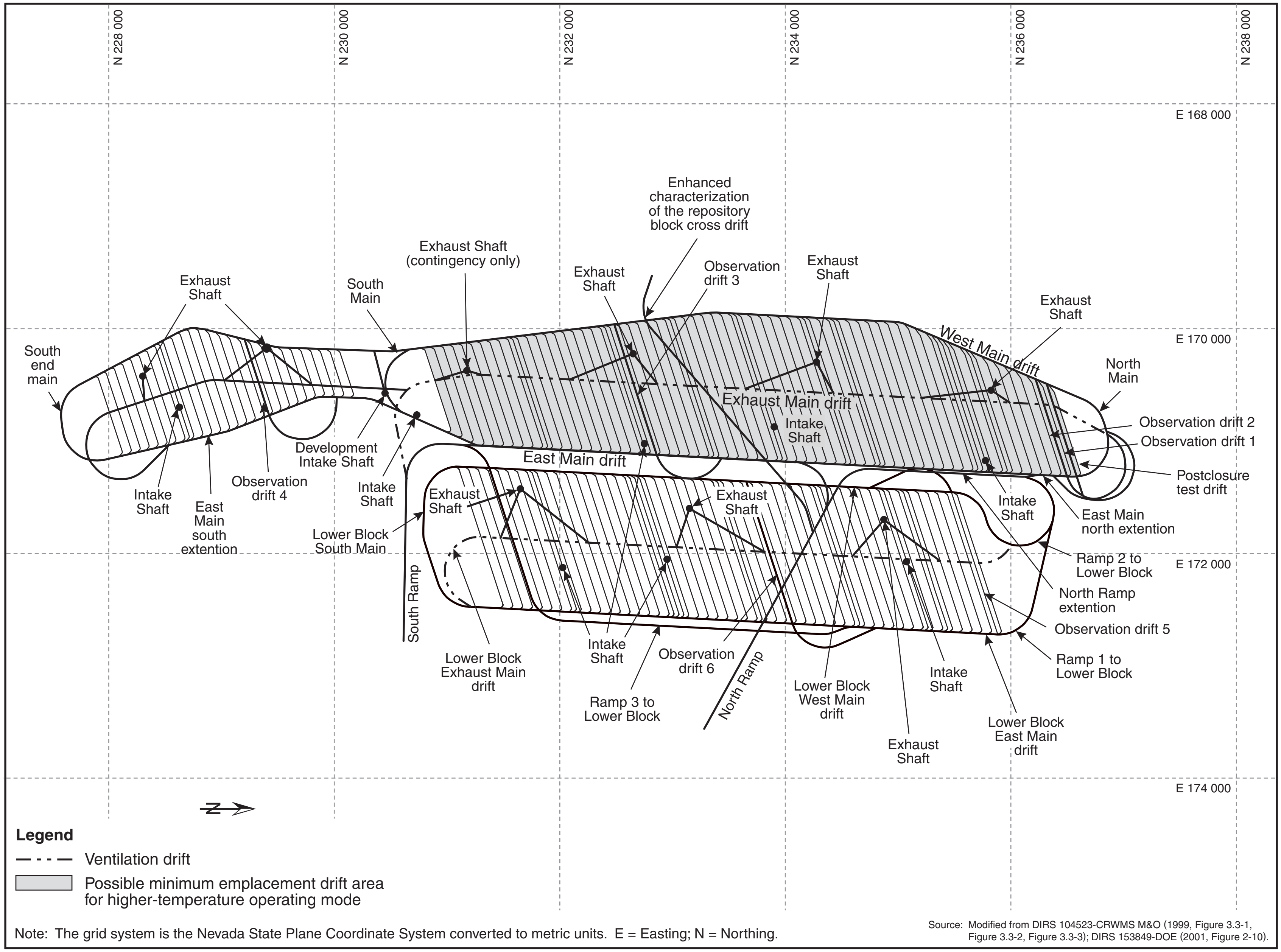


Figure 2-13. Flexible design operating mode repository layout showing possible maximum emplacement drift area.

Figure 2-14. Tunnel boring machine.

Main drifts would be concrete-lined, 7.6-meter (25-foot)-diameter tunnels excavated by tunnel boring machines. Rail lines and an overhead trolley system in the main drifts would enable the movement of electric-powered construction and waste package handling vehicles. The East Main drift was excavated as part of site characterization activities but was not lined with concrete. During the operation and monitoring phase, the main drifts would support both subsurface development and waste package emplacement, which would occur simultaneously. Ventilation barriers creating airlocks would separate the emplacement and development sides of the repository, and the ventilation system would maintain the emplacement side at a lower pressure than the development side. This would ensure that any air transfer would be from the development side to the emplacement side.

The flexible design is based on an emplacement drift spacing of approximately 81 meters (266 feet) (DIRS 153849-DOE 2001, Section 2.3.1.1). Emplacement drifts would be 5.5-meter (18-foot)-diameter tunnels connecting the main drifts; they could have steel ribbing. These drifts would be excavated by an electric-powered tunnel boring machine. Remotely operated steel isolation doors at the emplacement drift entrances would prevent unauthorized human access and reduce radiation exposure to personnel.

As noted above, tunnel boring machines would excavate the emplacement drifts and most main drifts. DOE would use other mechanical excavators in areas where tunnel boring machines were impractical (for example, excavating turnouts and small alcoves) or industry-standard drill and blast techniques in limited applications where mechanical excavators were impractical. Ventilation shafts [8.0 meters (26 feet) in diameter] would be excavated from the surface to the repository using mechanical or drill-and-blast techniques. (DIRS 153849-DOE 2001, p. 2-95). Specialized equipment would move excavated rock in the subsurface to the conveyor system that would move the rock to the excavated rock storage area on the surface. During drift excavation, water supplied to the subsurface in pipelines would be used for dust control at the excavation location and along the conveyor carrying excavated rock. Some of the water would be removed from the subsurface with the excavated rock, some would evaporate and be removed in the ventilation air, and the remainder would be collected in sumps near the point of use and pumped to the evaporation pond at the South Portal. DOE could recycle the water discharged to the evaporation pond for surface dust suppression activities. Controls would be established, as necessary, to ensure that water application for subsurface (and surface) dust control would not affect repository performance.

2.1.2.2.2 *Ventilation*

The repository design uses ventilation shafts to provide airflow to the subsurface during construction, emplacement, and performance monitoring. It also provides positive pressure ventilation flow for the construction and development of the repository and negative pressure ventilation flow in the emplacement drifts. Further, the design includes monitoring for radioactive contamination and preventive measures to achieve mitigation against the spread of such contamination. The development side would be isolated from the emplacement side. Table 2-2 lists the number of ventilation shafts and flow rates.

The flexible design uses an emplacement drift forced-air ventilation rate of 15 cubic meters (530 cubic feet) per second in each emplacement drift to control temperatures in the rock between the emplacement drifts, at the drift wall, and at the waste package surface to meet thermal goals. Figure 2-12 shows the general airflow pattern for ventilation of the emplacement drifts under the higher-temperature repository operating mode, using a representative section of a fully developed repository. In the basic ventilation design, fresh air would enter through the surface ends of intake shafts and ramps and would flow to the East and West Mains. From the mains, air would enter the emplacement, performance confirmation, or reserve drifts and flow to exhaust raises near the center of each drift. The exhaust raises would direct the airflow down to the exhaust main, where it would continue to an exhaust shaft and then to the surface.

Fans at the surface ends of the exhaust shafts would provide the moving force for the subsurface repository airflow. The fans would have enough power to exhaust the maximum amount of air required during the emplacement, monitoring, and closure periods. The volume of air moved by the fans would be adjustable to meet cooling requirements as they varied over time. The fans would draw air through the exhaust mains at a rate that ensured that air would always flow into the emplacement drifts from the main drifts, never allowing air to recirculate back to the main drifts.

Ventilation under the higher-temperature repository operating mode would remove at least 70 percent of the heat generated by the waste inventory during the preclosure period (DIRS 153849-DOE 2001, Section 2.1.2.2). The peak ventilation air temperature of 58°C (about 136°F) for a 1.4-kilowatt-per-meter linear thermal load would occur about 10 years into the preclosure period and would decrease thereafter (DIRS 150941-CRWMS M&O 2000, pp. 4-24 to 4-25). This temperature is lower than the exhaust air temperature of many industrial processes, such as powerplants and manufacturing facilities. The peak ventilation air temperature under the lower-temperature repository operating mode would be lower than that described above.

Ventilation requirements for emplacement drifts would vary according to the activities conducted in those drifts. Prior to emplacement, ventilation would provide fresh air and control dust levels to ensure an acceptable environment for construction personnel. During emplacement, ventilation would maintain drift temperatures within an acceptable range for equipment operation.

While DOE was conducting concurrent development and emplacement operations, it would maintain two separate ventilation systems, one for each operational area (development and emplacement). This separation would be accomplished by placing airlocks in the main drifts to ensure physical separation of the air space between the two areas. On the development side, the ventilation system would work under positive pressure, with air forced in through the development intake shaft or the South Ramp through a duct and exhausted through the South Ramp. On the emplacement side, the required ventilation facilities for the commissioned emplacement drifts would be available and operational in their final configuration; the ventilation system would work under negative pressure by drawing air out through the exhaust main (through the exhaust or "hot" side of the exhaust main), and from there through the exhaust shafts.

2.1.2.2.3 *Waste Package Emplacement Operations*

DOE would transport both the waste package and metal emplacement pallet as an integral unit from the Waste Handling Building to the prepared *ground support* in the emplacement drift. The transport of each waste package to the subsurface would start after the loading of a waste package and its emplacement pallet on a bedplate (railcar) transporter in the Waste Handling Building and then into the shielded section of the transporter. At its closed end the transporter would be coupled to a manned primary electric-powered locomotive (trolley). A manned secondary electric-powered locomotive would then be coupled to the transporter at the door end outside the Waste Handling Building (DIRS 153849-DOE 2001, Section 2.3.4.4.1). All waste packages would be transported by trolley underground through the North Ramp and into the emplacement area main drift. On arrival at the emplacement drift, the secondary locomotive would be uncoupled from the transporter, which would then be pushed into the emplacement drift turnout by the primary locomotive and stopped short of the isolation doors and loading dock. The operators would leave, and the locomotive operation would proceed by remote control. The isolation doors would be opened remotely, as would the transporter doors. Under remote control, the primary locomotive would push the waste package transporter into the off-loading dock. The waste package and pallet, seated on the bedplate, would be rolled out of the transporter, under remote control, to stop on the transfer section of the railcar. The remote-controlled gantry would straddle the waste package and pallet, lift the waste package and pallet from the bedplate, and carry them to the designated location in the emplacement drift. The bedplate would be rolled back into the waste package transporter, the transporter doors would be closed, and the transporter would be moved back to the access main drift using the primary locomotive under remote control. The isolation doors in the turnout would be closed, allowing the locomotive operators to recouple the secondary locomotive to the railcar. The empty transporter would be returned to the Waste Handling Building to pick up the next waste package (DIRS 153849-DOE 2001, Section 2.3.4.4.1).

DOE has developed plans for waste package retrieval for normal and off-normal conditions. Waste package retrieval under normal conditions would use the same subsurface equipment and facilities as emplacement, but in reverse order. This would provide a built-in capability for retrieval that could be readily implemented. Individual waste package removal for inspection, testing, and maintenance reasons is not considered retrieval; however, waste package removal for these purposes, if needed, would involve the same equipment and operational steps. Alternative waste package retrieval equipment and processes have been identified for off-normal conditions when normal retrieval procedures could be difficult or impossible to execute. Additionally, support equipment (equipment to remove obstacles, prepare surfaces, or install temporary ground supports) that could be used in retrieval operations under off-normal conditions has been identified. The equipment and processes would support various scenarios such as repair of the railing system, repositioning the emplacement pallet and waste package, or cleaning or removal of debris. All retrieval scenarios include radiation and temperature controls and other administrative controls, as needed, to conduct a safe retrieval operation (see DIRS 153849-DOE 2001, Section 2.3.4.6).

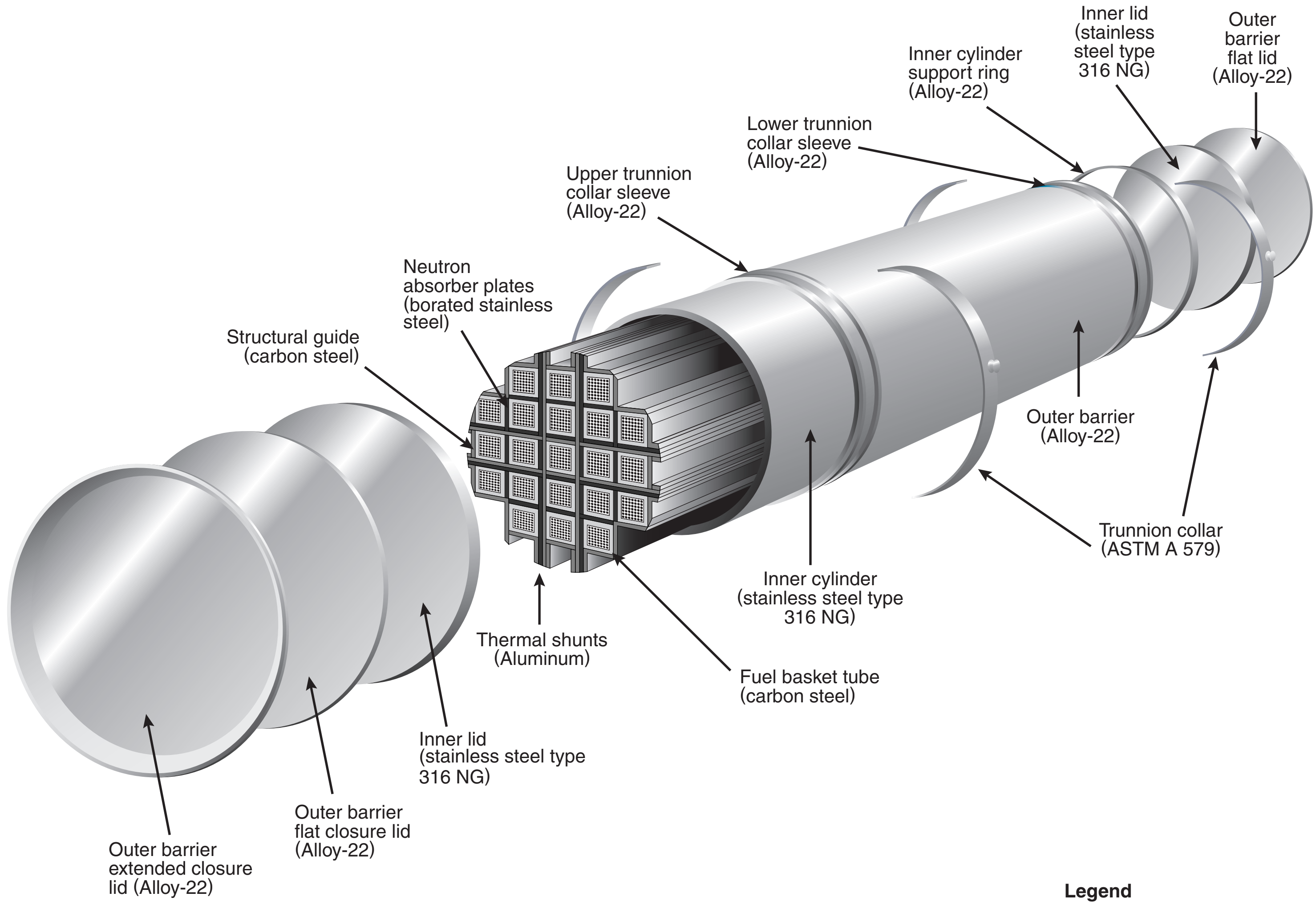
2.1.2.2.4 *Engineered Barrier Design*

Engineered barriers would include those components in the emplacement drifts that would contribute to waste containment and isolation. The design includes the following components as engineered barriers: (1) waste package, (2) emplacement drift *invert*, (3) *drip shield*, and (4) to a lesser extent, ground support (DIRS 153849-DOE 2001, Section 2.4). The following sections describe the details of these components.

2.1.2.2.4.1 Waste Package and Drip Shields. The function of the waste package would change over time. During the operation and monitoring phase, the waste packages would function as the vessels for safely handling, emplacing and, if necessary, retrieving their contents. After closure, the waste packages would be the primary engineered barrier to inhibit the release of radioactive material to the environment. The waste package design consists of two closed concentric cylinders in which DOE would place the waste forms.

The waste package would have a corrosion-resistant *Alloy-22* outer shell and a stainless-steel (Type 316NG) inner shell to provide structural support (DIRS 153849-DOE 2001, Section 3). Alloy-22 consists mostly of nickel, chromium (up to 22.5 percent), and molybdenum (up to 14.5 percent). Type 316NG stainless steel consists mostly of iron, chromium (up to 18 percent), nickel (up to 14 percent), and molybdenum (up to 3 percent) (DIRS 153849-DOE 2001, Section 3.4.1.1). In addition, the waste package would have a top lid design that consisted of three lids. The innermost lid would be stainless steel welded to the stainless-steel shell. The middle and outer lids would be Alloy-22, welded to the Alloy-22 outer shell (DIRS 153849-DOE 2001, Section 3) (see Figure 2-15). The highly corrosion-resistant Alloy-22 outer shell of the waste package would protect the underlying structural material from corrosive degradation, while the strong internal structural material would support the thinner corrosion-resistant material.

A drip shield with a nominal thickness of 1.5 centimeters (0.6 inch) of highly corrosion-resistant titanium would be placed over the waste package just before repository closure. The titanium drip shield and the Alloy-22 outer cylinder would provide two diverse engineered corrosion barriers to protect the waste from contact with water. The use of two distinctly different corrosion-resistant materials would reduce the *probability* that a single mechanism could cause the failure of both materials. Figure 2-16 shows a side view of a drip shield and an end view of the waste package and drip shield.



Legend

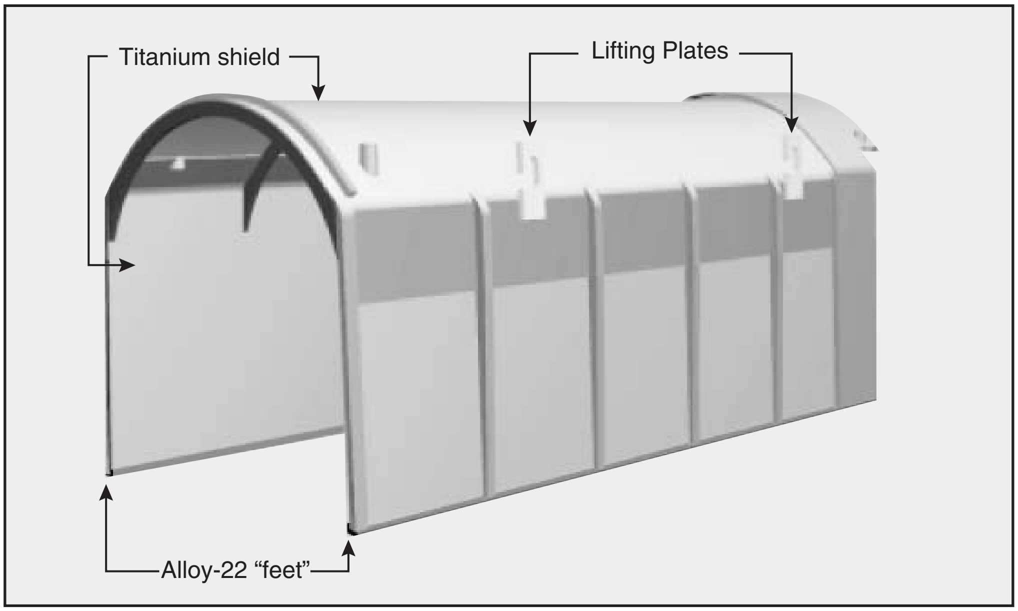
ASTM	American Society for Testing and Materials
NG	Nuclear grade stainless steel
SS	Stainless steel

Drawing not to scale.

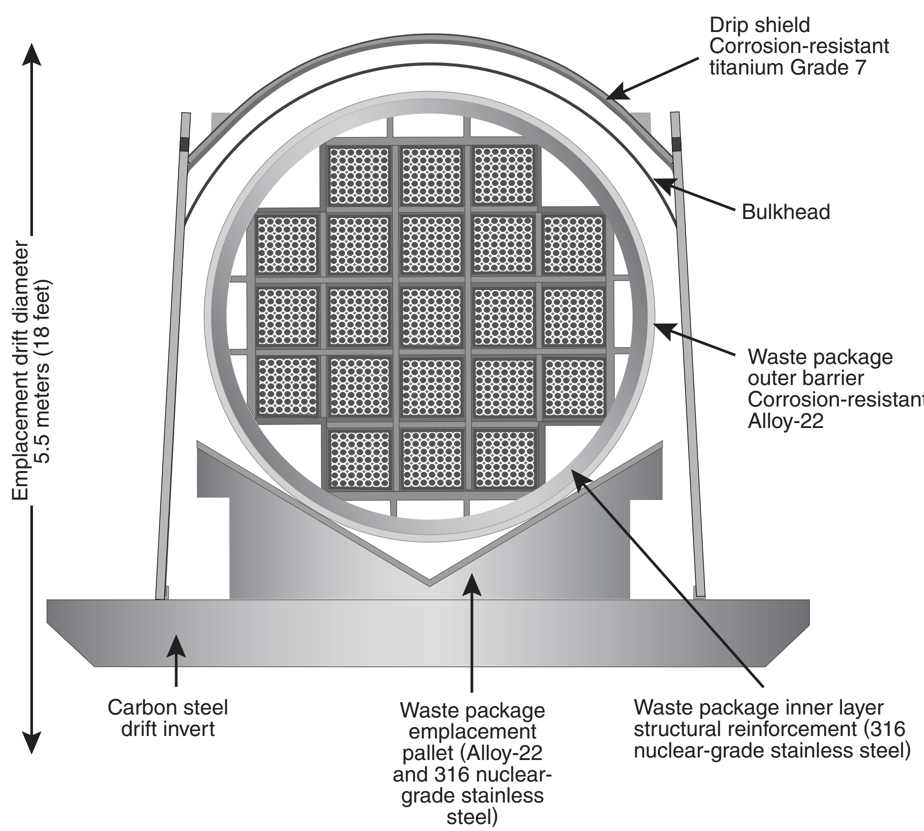
Source: Modified from DIRS 153849-DOE (2001, Figure 3-2).

Notes: Glossary contains definitions of terms.

Figure 2-15. Waste package for commercial spent nuclear fuel (pressurized-water reactor waste package).



Drip shield



Drawing not to scale.

Source: Modified from DIRS 153849-DOE (2001, Figures 2-73 and 3-1).

Figure 2-16. Drip shield and waste package containing commercial spent nuclear fuel with drip shields in place.

Commercial spent nuclear fuel, DOE spent nuclear fuel, and immobilized plutonium contain *fissile material,* which is material capable, in principle, of sustaining a fission *chain reaction*. For a self-sustaining chain reaction to take place, a critical mass of fissile material—uranium-233 or -235 or one of several plutonium isotopes—must be arranged in a critical configuration. Waste packages would be loaded with fissile material and *neutron absorbers*, if needed, so *criticality* could not occur even in the unlikely event that the waste package somehow became full of water.

After the repository ventilation was stopped and heat produced by the waste packages had decreased (both of which would happen after closure), moisture could enter the emplacement drifts in liquid or vapor form. The function of the drip shields would be to divert water that dripped from the drift walls and water vapor that condensed on the surface of the drip shields away from waste packages, prolonging their longevity and structural integrity. Water dripping on the waste packages would increase the likelihood of corrosion. For the EIS analyses, the drip shields were considered to be a single continuous barrier for the entire length of the emplacement drift if the separation between the waste packages was less than 1.6 meters (5.3 feet). If the separation was greater than 1.6 meters, the EIS analyses used stand-alone drip shields. They would be strong enough to protect the waste packages from damage by rockfalls resulting from degradation of the drift walls, withstanding damage from rocks weighing several tons (DIRS 153849-DOE 2001, Section 2.4.4). To maintain waste package retrievability, the drip shields, via remote control, would be placed over the waste packages just before repository closure.

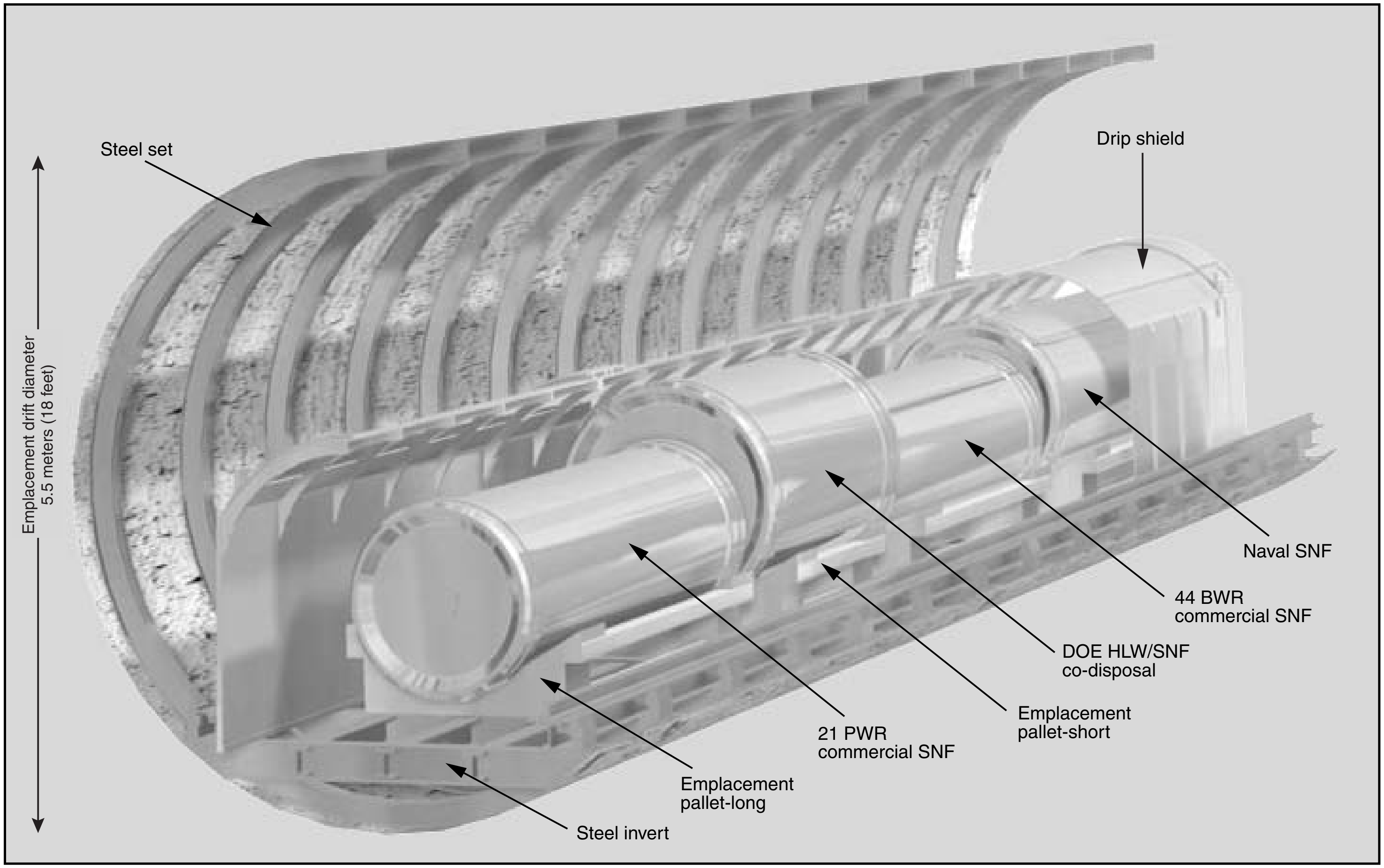
2.1.2.2.4.2 Ground Support Structures. In underground openings, ground support structures provide tunnel stability and help prevent rockfall. For the proposed repository, the ground support system would address in-place loads, construction loads, potential loads from repository operations, and loads from potential seismic occurrences (DIRS 153849-DOE 2001, Section 2.3.4.1.2). The system would consist of steel sets with welded-wire fabric and fully grouted rockbolts.

The main drifts, turnouts, exhaust main, and ventilation shafts (nonemplacement areas) would have separate initial and final ground support systems. Initial ground support methods would vary depending on ground conditions, and would include a combination of steel sets, welded-wire fabric, rockbolts, and shotcrete (concrete sprayed onto the surface at high pressure). The final ground support system for the nonemplacement drift areas would be cast-in-place concrete liners.

The observation drifts, which would support the performance confirmation program, would have a ground support system similar to that for the emplacement drifts if they were excavated with a tunnel boring machine. Otherwise, they would have a combination of support systems, including steel sets, welded-wire fabric, rockbolts, and shotcrete, depending on ground conditions (DIRS 153849-DOE 2001, Section 2.3.4.1.2.2).

2.1.2.2.4.3 Emplacement Pallets. The repository design uses emplacement pallets to support the waste packages. A waste package would be placed horizontally on its support (an emplacement pallet) in the Waste Handling Building and transported to the drifts as a unit. Figure 2-17 shows a conceptual design of spent nuclear fuel and high-level radioactive waste package types in an emplacement drift on emplacement pallets, drip shields, and steel sets for ground support. The emplacement pallet would support the waste package in the drift. While loaded with a waste package, the pallet would be lifted by lifting points at the support, directly under the upper stainless-steel tubes, as shown in Figure 2-18. The pallet design would meet the design requirements for structural strength during lifting under the weight of the heaviest waste package (DIRS 153849-DOE 2001, Section 2.3.4.4.2).

Figure 2-19 shows an emplacement pallet, and Figure 2-18 shows a waste package on an emplacement pallet. There would be two sizes of pallet: one that would hold most waste packages and a second, shorter version for the DOE codisposal waste package (DIRS 153849-DOE 2001, Section 2.3.4.4.2). The emplacement pallets would be made of Alloy-22 plates welded together to form the waste package



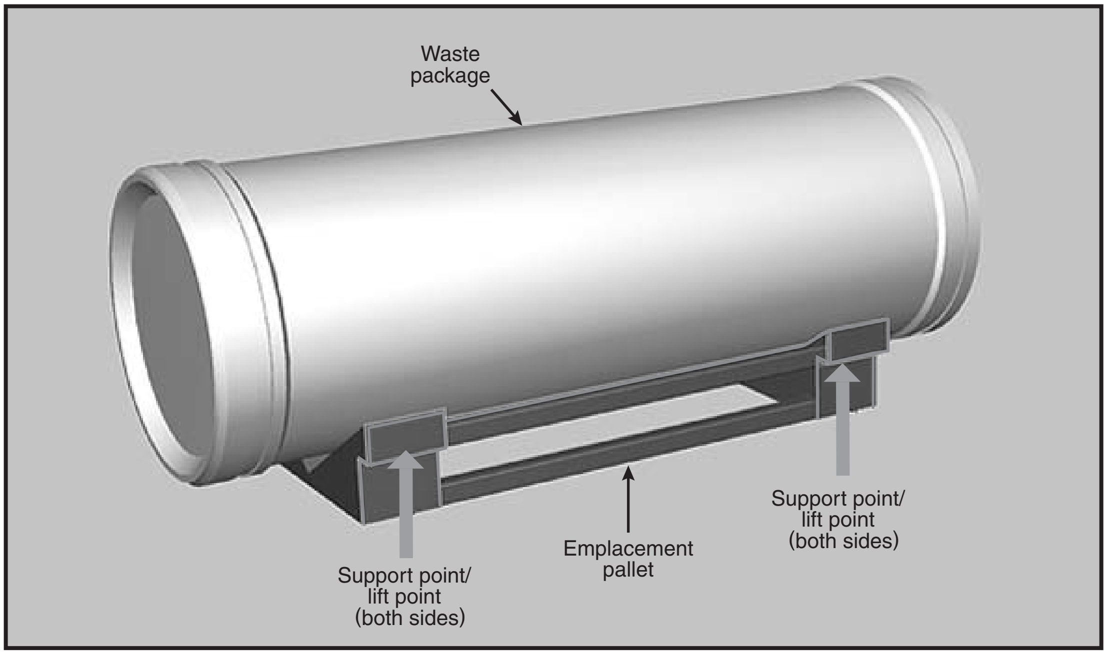
Drawing not to scale.

Legend

BWR Boiling-water reactor
DOE U.S. Department of Energy
HLW High-level radioactive waste
PWR Pressurized-water reactor
SNF Spent nuclear fuel

Source: Modified from DIRS 153849-DOE (2001, Figure 2-77).

Figure 2-17. Typical section of emplacement drift with waste packages and drip shields in place.



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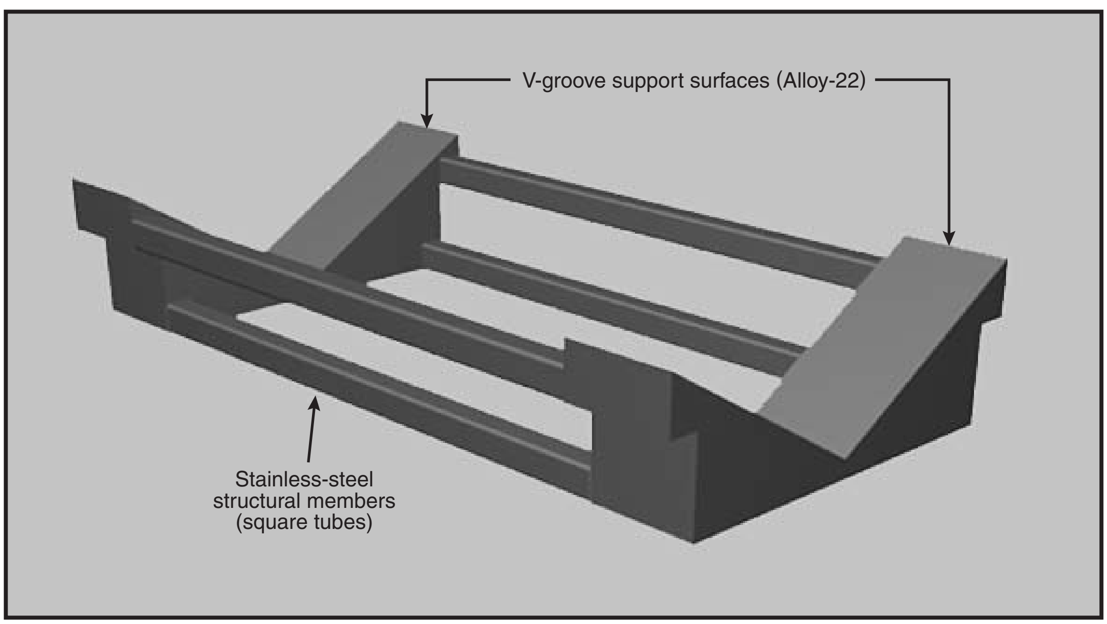
Source: DIRS 153849-DOE (2001, Figure 2-52).

Figure 2-18. Waste package on an emplacement pallet.



Drawing not to scale.

Source: DIRS 153849-DOE (2001, Figure 2-51).

Figure 2-19. Emplacement pallet.

supports. Two supports would be connected by square stainless-steel tubing to form the completed emplacement pallet. The supports would have a V-groove top surface to accept all waste package diameters. Emplacement pallet surfaces that contacted the waste package would be Alloy-22, the same material used for the outer package shell.

The ends of the waste package would extend past the ends of the emplacement pallet, which would allow placement of the waste packages end-to-end, within 10 centimeters (4 inches) of each other, without interference from the pallets (DIRS 153849-DOE 2001, Section 2.3.4.4.2).

2.1.2.3 Performance Confirmation Program

Performance confirmation refers to the program of tests, experiments, and analyses that DOE would conduct to evaluate the adequacy of the information used to demonstrate compliance that the repository would meet performance objectives. The performance confirmation program, which would continue through the licensing and construction phases and until the closure phase, would include elements of site testing, repository testing, repository subsurface support facilities construction, and waste package testing. Some of these activities would be a continuation of activities that began during site characterization.

To support performance confirmation activities, DOE would provide some specialized surface and subsurface facilities. DOE would build observation drifts below and above the *repository horizon* (DIRS 153849-DOE 2001, Section 2.5.2.2). The data-collection focus of the performance confirmation program would be to collect additional information to confirm the data used in the License Application. If the Nuclear Regulatory Commission granted a license, the activities would focus on monitoring and data collection for performance parameters important to terms and conditions of the license.

Performance confirmation drifts would be built about 15 meters (50 feet) above and below the emplacement drifts. DOE would drill boreholes from the performance confirmation drifts that would approach the rock mass near the emplacement drifts; instruments in these boreholes would gather data on the thermal, mechanical, hydrological, and chemical characteristics of the rock after waste emplacement. DOE would acquire performance confirmation data by sampling and mapping, from instruments in performance confirmation drifts or along the perimeter mains, ventilation exhaust monitoring, remote inspection systems in emplacement drifts, and monitoring of water quality in wells.

DOE would use the performance confirmation program data to evaluate system performance and to confirm predicted system response. If the data determined that actual conditions differed from those predicted, the Nuclear Regulatory Commission would be notified and remedial actions would be undertaken to address any such condition (DIRS 153849-DOE 2001, Sections 2.5 and 4.6).

2.1.2.4 Repository Closure

Before closure, an application to amend the Nuclear Regulatory Commission license would have to provide an update of the assessment of repository performance for the period after closure, as well as a description of the program for postclosure monitoring to regulate or prevent activities that could impair the long-term isolation of waste. The postclosure monitoring program, as required by Section 801(c) of the Energy Policy Act of 1992 and as required by the Nuclear Regulatory Commission (10 CFR Part 63), would include the monitoring activities that would be conducted around the repository after the facility had been closed and sealed. Regulations at 10 CFR 63.51(a)(1) and (2) would require the submittal of a license amendment for closure of the repository (see Section 2.3.4.8). The details of this program would be delineated during processing of the license amendment for closure. Deferring the delineation of this program to the closure period would allow identification of appropriate technology, including technology that might not be currently available (DIRS 153849-DOE 2001, Sections 2.3.4.8 and 4.6.1).

For the higher-temperature repository operating mode, this EIS assumes closure would begin 100 years after the start of emplacement (76 years after the completion of emplacement). In contrast, repository closure for the lower-temperature repository operating mode could begin 125 to 300 years after the completion of emplacement. Closure would take 10 years for the higher-temperature mode (DIRS 150941-CRWMS M&O 2000, p. 6-22) and between 11 and 17 years for the lower-temperature mode, depending on the waste package spacing.

Closure of the subsurface repository facilities would include the emplacement of the drip shields; removal and salvage of equipment and materials; filling of the main drifts, access ramps, and ventilation shafts; and sealing of openings, including ventilation shafts, access ramps, and boreholes. Filling would require surface operations to obtain fill material from the excavated rock storage area or another source, and processing (screening, crushing, and possibly washing) the material to obtain the required characteristics. Fill material would be transported on the surface in trucks and underground in open gondola railcars. A fill placement system would place the material in the underground main drifts and ramps. DOE would place the seals for shafts, ramps, and boreholes strategically to reduce *radionuclide* migration over extended periods, so these openings could not become pathways that could compromise the repository's postclosure performance (DIRS 153849-DOE 2001, Section 2.3.4.8).

Decommissioning surface facilities would include decontamination activities, if required, and facility dismantling and removal. Equipment and materials would be salvaged, recycled, or reused, if possible. Site reclamation would include restoring the site to as near its preconstruction condition as practicable, including the recontouring of disturbed surface areas, surface *backfill,* soil buildup and reconditioning, site revegetation, site water course configuration, and erosion control, as appropriate.

2.1.3 TRANSPORTATION ACTIVITIES

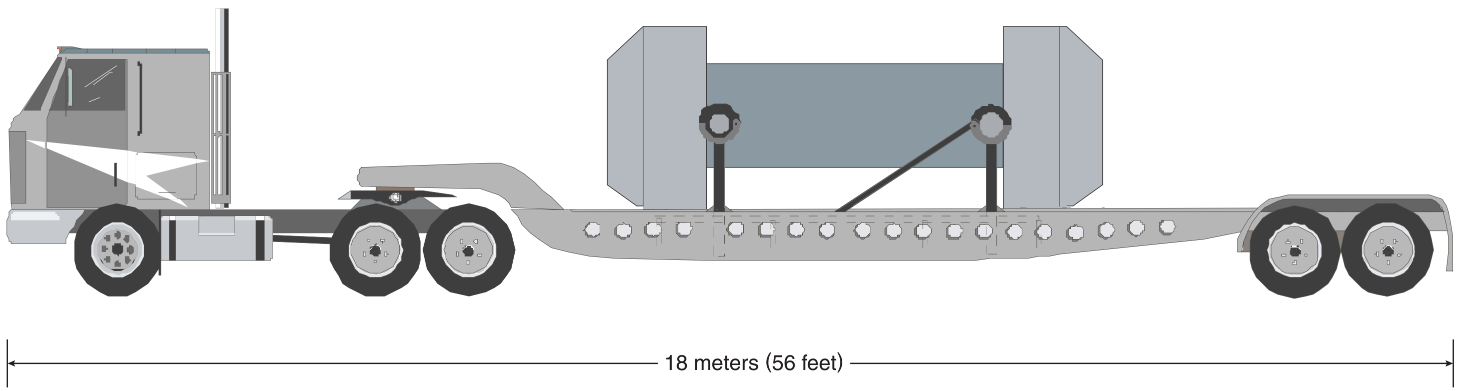
Under the Proposed Action, DOE would transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository. The Naval Nuclear Propulsion Program would transport *naval spent nuclear fuel* from the Idaho National Engineering and Environmental Laboratory to the repository. Naval spent nuclear fuel is one of the DOE fuels considered in this EIS. Transportation activities would include the loading of these materials for shipment at generator sites (Section 2.1.3.1), transportation of the materials to the Yucca Mountain site using truck, rail, heavy-haul truck, or barge [see Sections 2.1.3.2 (National) and 2.1.3.3 (Nevada)], and *shipping cask* manufacturing, maintenance, and disposal (Section 2.1.3.4). Chapter 6 and Appendix J provide further discussion of transportation processes considered.

2.1.3.1 Loading Activities at Commercial and DOE Sites

This EIS evaluates the loading of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites for transportation to the proposed repository at Yucca Mountain. Activities would include preparing the spent nuclear fuel or high-level radioactive waste for delivery, loading it in a shipping cask, and placing the cask on a vehicle (see Figures 2-20 and 2-21) for shipment to the repository. This EIS assumes that at the time of shipment the spent nuclear fuel and high-level radioactive waste would be in a form that met approved acceptance and disposal criteria for the repository.

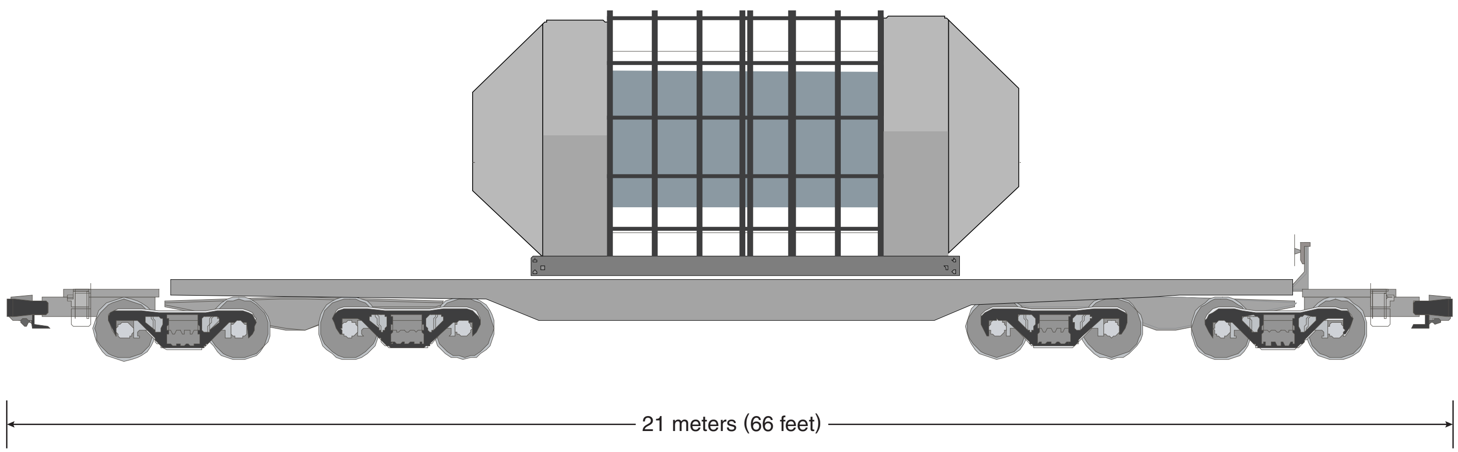
2.1.3.2 National Transportation

National transportation includes the transport of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site using existing highways (see Figure 2-22a) and railroads (see Figure 2-23a). Figures 2-22b and 23b show the representation highway and rail routes, respectively, used in the EIS analysis to estimate transportation-related impacts (see Section 6.2 for further discussion). Heavy-haul trucks could be used to transport spent nuclear fuel from commercial



Source: DIRS 104782-Kelderhouse (1999, p. 7).

Figure 2-20. Artist's conception of a truck cask on a legal-weight tractor-trailer truck.



Source: DIRS 104782-Kelderhouse (1999, p. 8).

Figure 2-21. Artist's conception of a large rail cask on a railcar.

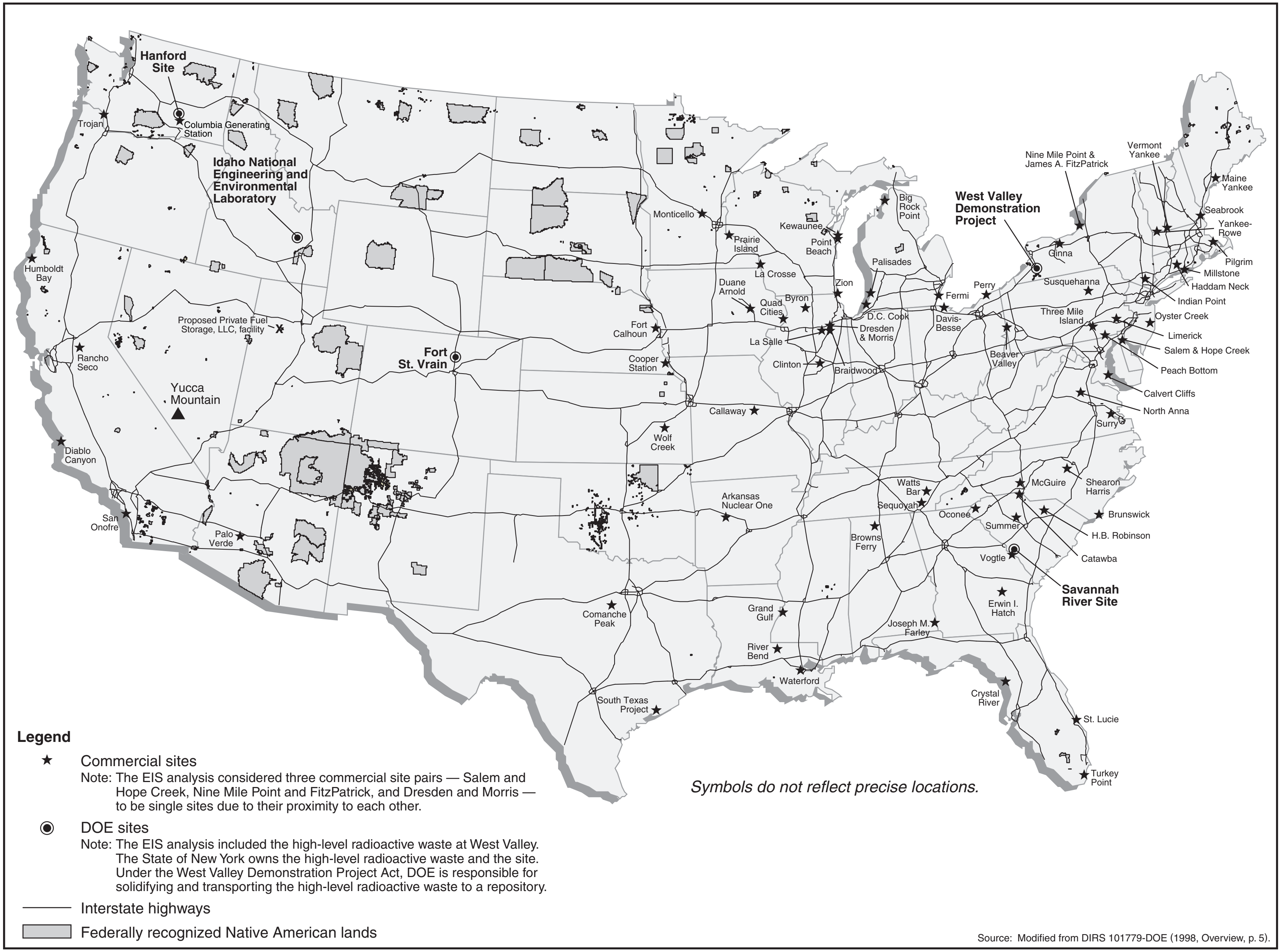


Figure 2-22a. Commercial and DOE sites and Yucca Mountain in relation to the U.S. Interstate Highway System.

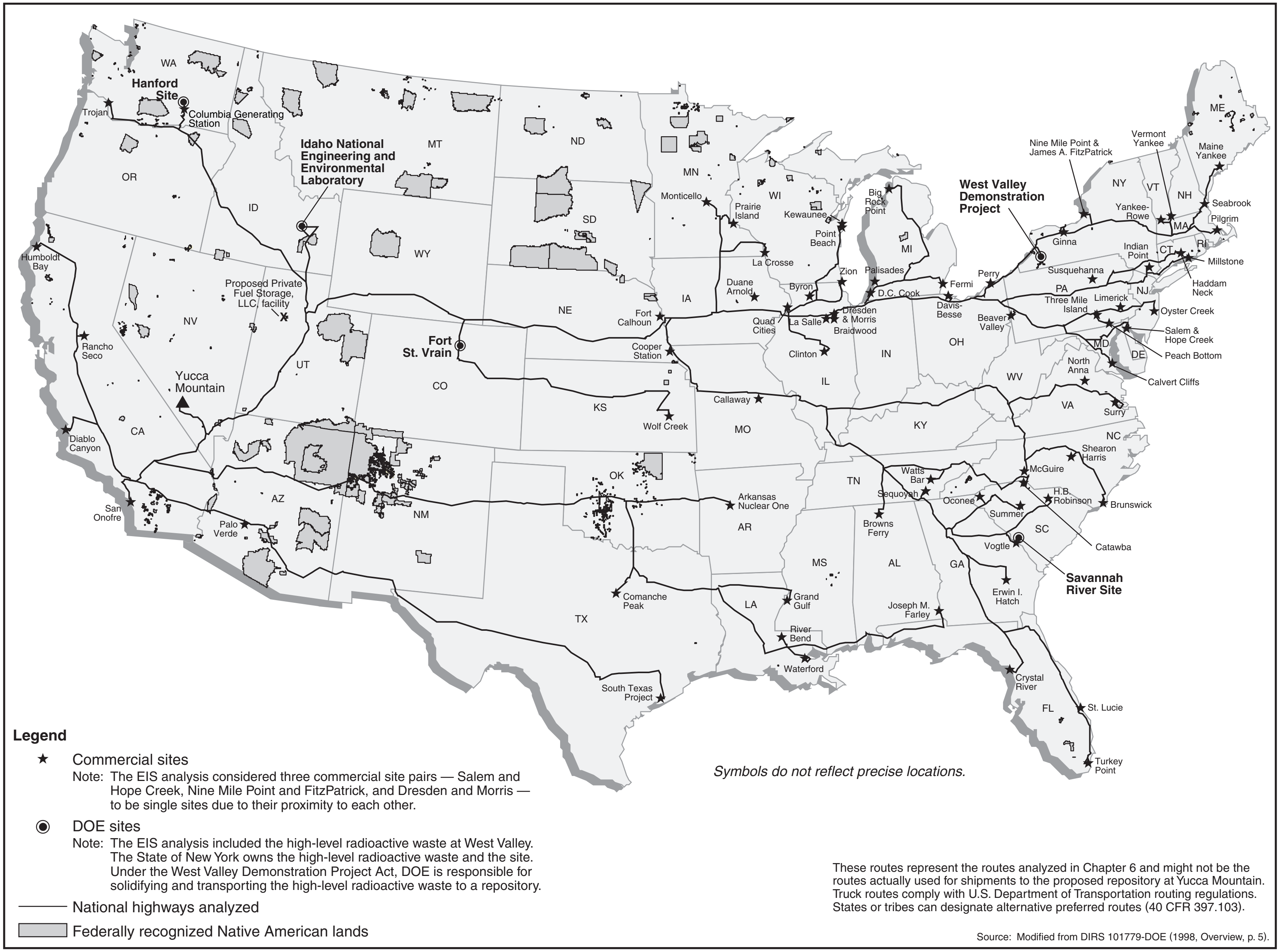


Figure 2-22b. Representative truck routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

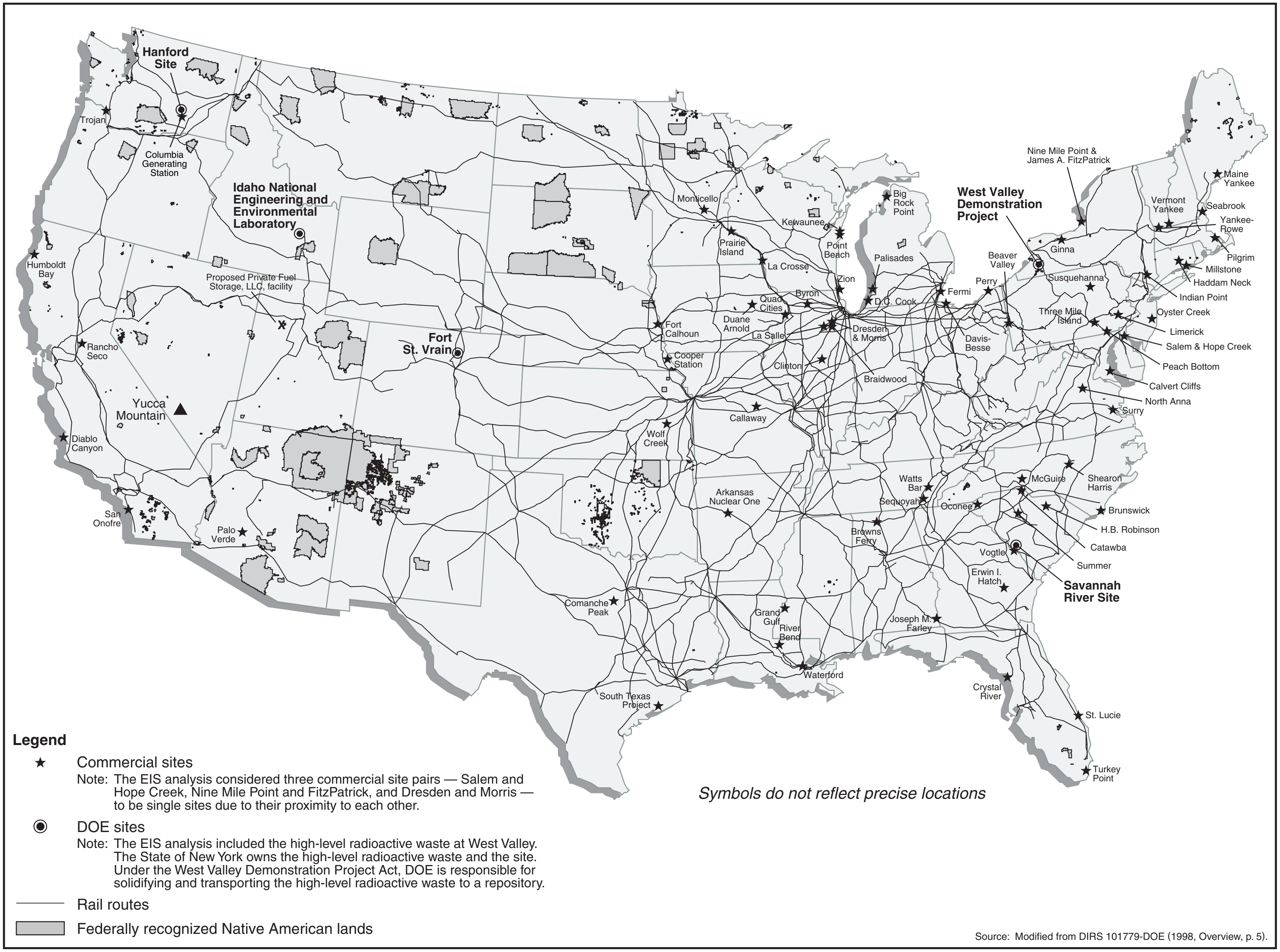


Figure 2-23a. Commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system.

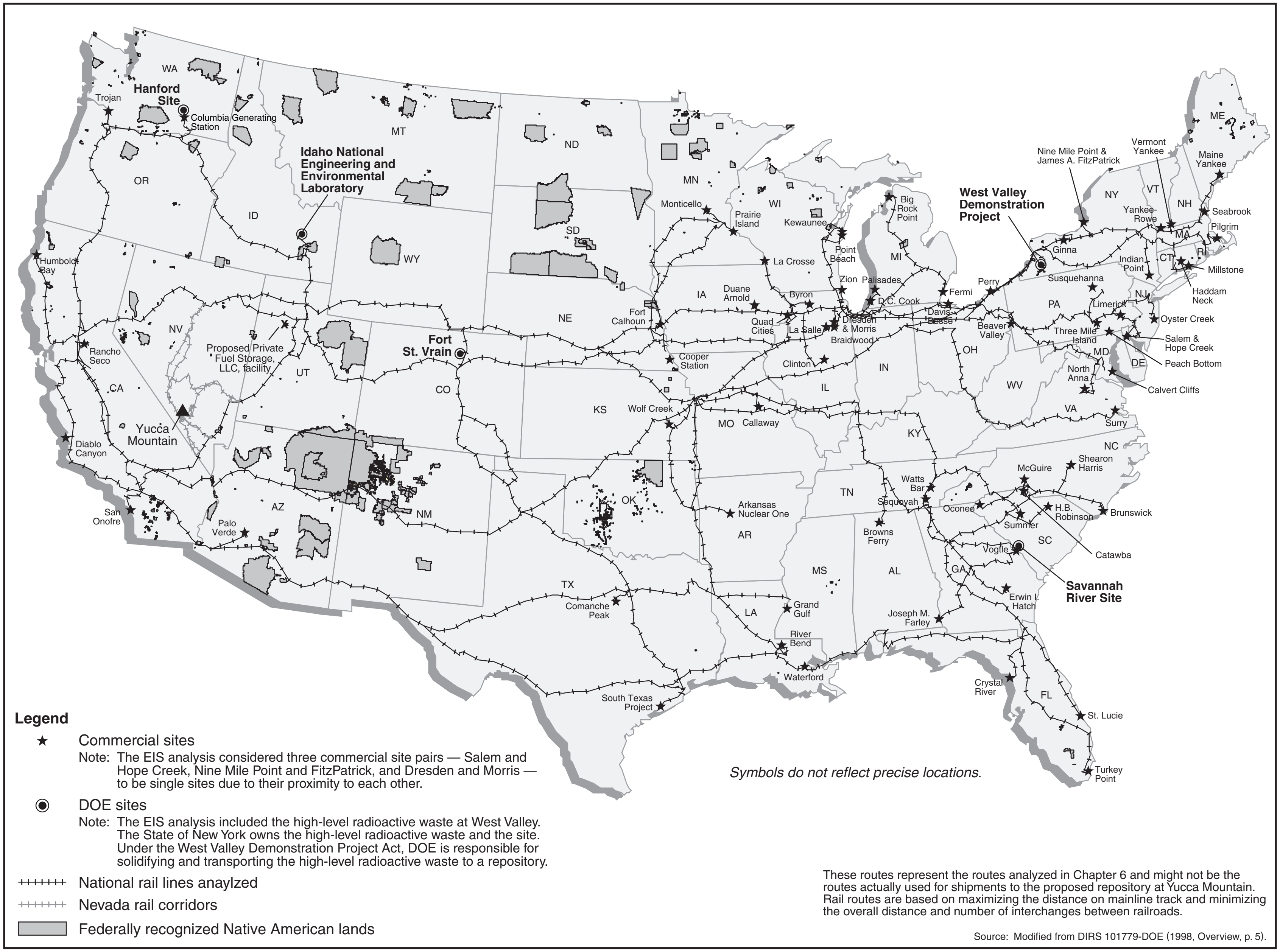


Figure 2-23b. Representative rail routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

sites that did not have rail access to a nearby rail access point. Such sites on navigable waterways could use barges to deliver spent nuclear fuel to a nearby rail access point. The transportation of spent nuclear fuel and high-level radioactive waste to the repository would comply with applicable regulations of the U.S. Department of Transportation and the Nuclear Regulatory Commission, as well as applicable state and local regulations.

DOE would use a satellite-based transportation tracking and communications system (such as TRANSCOM), to track current truck and rail shipments of spent nuclear fuel and high-level radioactive waste to the repository. This or a similar system could provide users (for example, DOE, the Nuclear Regulatory Commission, and state and tribal governments) with information about shipments to the repository and would enable communication between the vehicle operators and a central communication station. Additional escorts are required for shipments in heavily populated areas. In these areas, armed escorts would be required for highway and rail shipments (10 CFR 73.37). The use of a satellite-based communication and tracking system, such as TRANSCOM, is subject to Nuclear Regulatory Commission approval. Under Nuclear Regulatory Commission regulations, specific information about shipments, such as time of departure and location during travel, must not be publicly disclosed and is only available to officials designated by state governors. In addition, notification and sharing of shipment information with Native American tribes is the subject of a proposed Nuclear Regulatory Commission rulemaking.

Section 180(c) of the NWPA requires DOE to provide technical and financial assistance to states and tribes for training public safety officials in jurisdictions through which it plans to transport spent nuclear fuel and high-level radioactive waste. The training is to include procedures for the safe routine transportation of these materials and for emergency response. DOE is developing the policy and procedures for implementing this assistance and has started discussions with the appropriate organizations. The Department would institute these plans before beginning shipments to the repository.

In the event of an incident involving a shipment of spent nuclear fuel or high-level radioactive waste, the transportation carrier would notify local authorities and the central communications station monitoring the shipment. DOE would make resources available to local authorities as appropriate to mitigate such an incident.

2.1.3.2.1 *National Transportation Shipping Scenarios*

DOE would ship spent nuclear fuel and high-level radioactive waste from commercial and DOE sites using some combination of the legal-weight truck, rail, heavy-haul truck, and barge modes of transport. This EIS considers two national transportation mode-mix scenarios, which for simplicity are referred to as the mostly legal-weight truck scenario and the mostly rail scenario. These scenarios encompass the broadest range of operating conditions relevant to potential impacts to human health and the environment. Table 2-3 summarizes these scenarios, and Appendix J provides additional details.

Table 2-3. National transportation scenarios (percentage based on number of shipments).[a]

Material[a]	Mostly legal-weight truck	Mostly rail
Commercial SNF	100% by legal-weight truck	About 90% by rail; about 10% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail
DOE SNF	Mostly legal-weight truck; includes about 300 naval SNF shipments from INEEL to Nevada by rail	100% by rail

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory.

2.1.3.2.2 *Mostly Legal-Weight Truck Shipping Scenario*

Under this scenario, DOE would ship all high-level radioactive waste and most spent nuclear fuel from commercial and DOE sites to the Yucca Mountain site by legal-weight truck. About 53,000 shipments of these materials would travel on the Nation's Interstate Highway System during a 24-year period. There would be about 41,000 commercial spent nuclear fuel shipments and about 12,000 shipments of DOE spent nuclear fuel and high-level radioactive waste. The exception would be about 300 shipments of naval spent nuclear fuel that would travel from the Idaho National Engineering and Environmental Laboratory to Nevada by rail. The Department of the Navy prepared an EIS (DIRS 101941-USN 1996, all) and issued two Records of Decision (62 *FR* 1095, January 8, 1997; 62 *FR* 23770, May 1, 1997) on its spent nuclear fuel.

Truck shipments would use Nuclear Regulatory Commission-certified, reusable shipping casks secured on legal-weight trucks (Figure 2-20). With proper labels and vehicle placards (hazard identification) and vehicle and cask inspections, a truck carrying a shipping cask of spent nuclear fuel or high-level radioactive waste would travel to the repository on highway routes selected in accordance with U.S. Department of Transportation regulations (49 CFR 397.101), which require the use of *preferred routes*. These routes include the Interstate Highway System, including beltways and bypasses. Alternative preferred routes could be designated by states and tribes following Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with affected local jurisdictions and with any other affected states.

Shipments of naval spent nuclear fuel would travel by rail in reusable rail shipping casks certified by the Nuclear Regulatory Commission. These shipments would use applicable and appropriate placards and inspection procedures.

2.1.3.2.3 *Mostly Rail Shipping Scenario*

Under this scenario, DOE would ship most spent nuclear fuel and high-level radioactive waste to Nevada by rail, with the exception of material from commercial nuclear sites that do not have the capability to load large-capacity rail shipping casks. Those sites would ship spent nuclear fuel to the repository by legal-weight truck. Commercial sites that have the capability to load large-capacity rail shipping casks but do not have immediate rail access could use heavy-haul trucks or barges to transport their spent nuclear fuel to a nearby rail line. Under this scenario, about 9,000 to 10,000 railcars of spent nuclear fuel and high-level radioactive waste would travel on the nationwide rail network over a period of 24 years. Rail shipments would consist of Nuclear Regulatory Commission-certified, reusable shipping casks secured on railcars (see Figure 2-21). In addition, there would be about 1,000 legal-weight truck shipments. All shipments would be marked with the appropriate labels and placards and would be inspected in accordance with applicable regulations.

Some of the logistics of rail transportation to the repository would depend on whether DOE used general or *dedicated freight service*. General freight shipments of spent nuclear fuel and high-level radioactive waste would be part of larger trains carrying other commodities. A number of transfers between trains could occur as a railcar traveled to the repository. The basic infrastructure and activities would be similar between general freight and dedicated trains. However, dedicated train service would contain only railcars destined for the repository. In addition to railcars carrying spent nuclear fuel or high-level radioactive waste, there would be buffer and *escort cars*, in accordance with Federal regulations. DOE would use a satellite-based system to monitor all spent nuclear fuel shipments (see Section 2.1.3.2).

TERMS RELATED TO RAIL SHIPPING

General freight rail service: A railroad freight service that handles a number of shippers and commodities. Railcars carrying spent nuclear fuel or high-level radioactive waste could switch in railyards or on sidings to a number of trains as they traveled from commercial and DOE sites to Nevada.

Dedicated freight rail service: A railroad freight service that provides exclusive service to a shipper and often involves transportation of a single commodity. Use of a separate train with its own crew carrying spent nuclear fuel or high-level radioactive waste would avoid switching railcars between trains.

Buffer cars: Railcars placed in front and in back of those carrying spent nuclear fuel or high-level radioactive waste to provide additional distance from possibly occupied railcars. Federal regulations (49 CFR 174.85) require the separation of a railcar carrying spent nuclear fuel or high-level radioactive waste from a locomotive, occupied caboose, or carload of undeveloped film by at least one buffer car. These could be DOE railcars or, in the case of general freight service, commercial railcars.

Escort cars: Railcars in which escort personnel (for example, security personnel) would reside on trains carrying spent nuclear fuel or high-level radioactive waste.

2.1.3.3 Nevada Transportation

Nevada transportation is part of national transportation, but the EIS discusses it separately to highlight aspects of interest to Nevada. Depending on how a shipment was transported, DOE could use one of three options or modes of transportation in Nevada to reach the Yucca Mountain site: legal-weight trucks, rail, or heavy-haul trucks. Legal-weight truck shipments arriving in Nevada would travel directly to the Yucca Mountain site. Potential routes for legal-weight truck shipments in Nevada would comply with U.S. Department of Transportation regulations (49 CFR 397.101) for selecting “preferred routes” and “delivery routes” for motor carrier shipments of highway route-controlled quantities of radioactive materials. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103. Two interstate highways cross Nevada—I-80 in the north and I-15 in the south. I-15, the closest interstate highway to the proposed repository, travels through Salt Lake City, Utah, to southern California, passing through Las Vegas. Figure 2-24 shows the existing highway infrastructure in southern Nevada. The EIS analysis assumed that the proposed beltway around the urban core of Las Vegas (the Las Vegas Beltway) would be operational before 2010 and would be part of the Interstate Highway System.

Shipments arriving in Nevada by rail would travel to the repository site by rail or heavy-haul truck (legal-weight trucks could not be used due to the size and weight of the rail shipping casks). Existing rail lines in the State include two northern routes and one southern route; the Union Pacific Railroad owns both the northern and the southern routes. The northern routes pass through or near the cities of Elko, Carlin, Battle Mountain, and Reno. The southern route runs through Salt Lake City, Utah, to Barstow, California, passing through Caliente, Las Vegas, and Jean, Nevada. Figure 2-25 shows the Nevada rail infrastructure. Rail access is not currently available to the Yucca Mountain site, so DOE would have to build a branch rail line from an existing mainline railroad to the site or transfer rail casks to heavy-haul trucks at an intermodal transfer station for transport to the repository. In addition, some highways that DOE would use for heavy-haul trucks would need to be upgraded.

To indicate distinctions between available transportation options or modes in Nevada and to define the range of potential impacts associated with transportation in the State, this EIS analyzes three

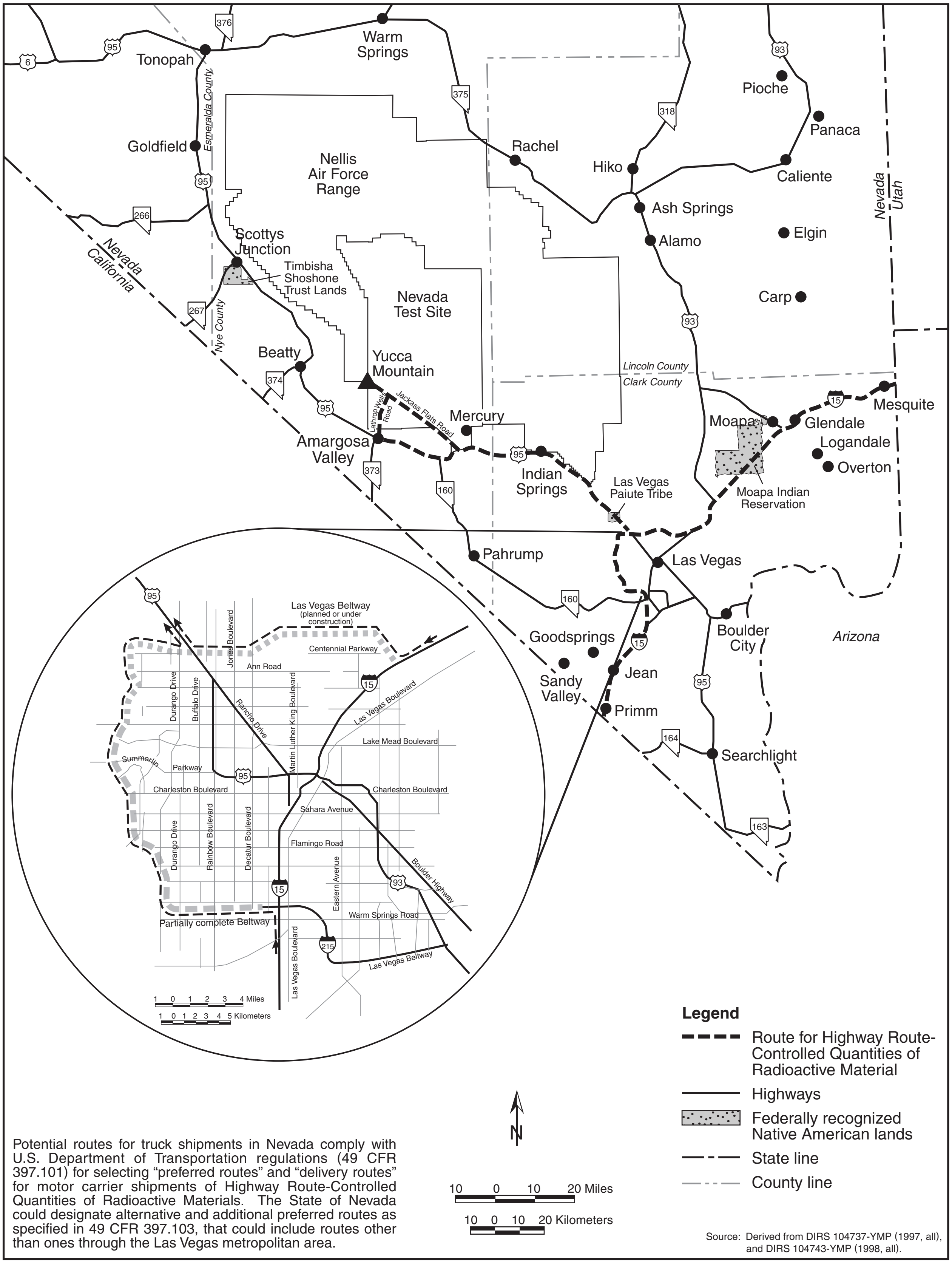


Figure 2-24. Potential Nevada routes for legal-weight truck shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

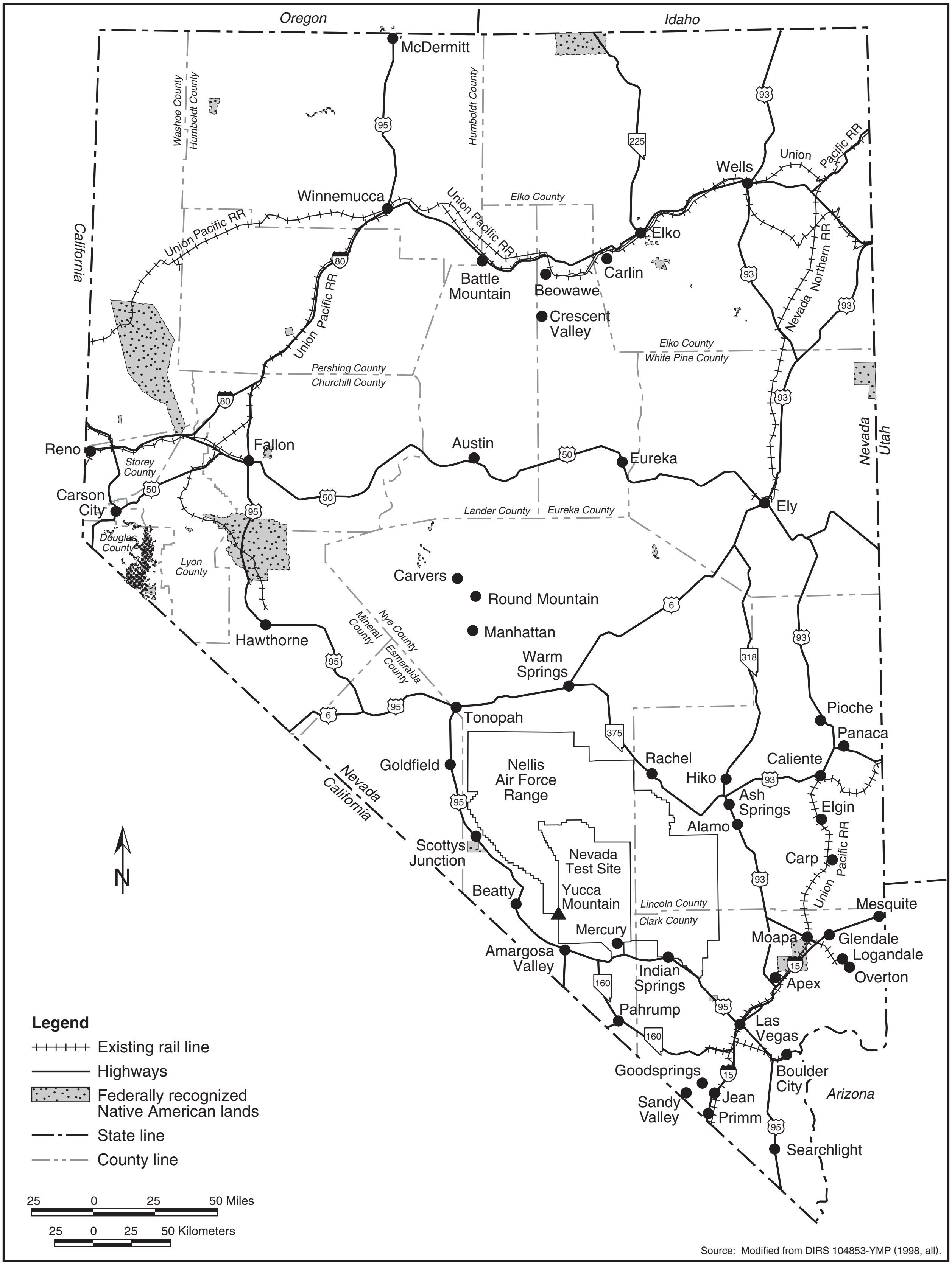


Figure 2-25. Existing Nevada rail lines.

transportation scenarios: the first, associated with the national mostly legal-weight truck scenario, is a Nevada legal-weight truck scenario; the second and third, both associated with the national mostly rail scenario, are rail transport directly to the Yucca Mountain site, and an intermodal transfer from railcar to heavy-haul truck for travel to the site. Table 2-4 summarizes the Nevada transportation scenarios.

Table 2-4. Nevada transportation shipping scenarios (percentage based on number of shipments).[a]

Material	Mostly legal-weight truck	Mostly rail	Mostly heavy-haul truck[b]
Commercial SNF	100% by legal-weight truck	About 90% by rail; about 10% by legal-weight truck	About 90% by heavy-haul truck; about 10% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail	100% by heavy-haul truck
DOE SNF	Mostly by legal-weight truck; includes about 300 naval SNF shipments by rail and heavy-haul truck	100% by rail	100% by heavy-haul truck

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
b. Rail shipment to intermodal transfer station, and heavy-haul truck shipment from intermodal transfer station to the repository.

The following sections describe the Nevada transportation scenarios and the implementing alternatives DOE is considering for a new branch rail line or a new intermodal transfer station and associated highway route for heavy-haul trucks.

2.1.3.3.1 *Nevada Legal-Weight Truck Scenario*

Under this scenario, DOE would use legal-weight trucks in Nevada to transport spent nuclear fuel and high-level radioactive waste to the repository. Naval spent nuclear fuel would be transported to Nevada by rail. In Nevada, DOE would use heavy-haul trucks to transport these 300 shipments. DOE would establish an intermodal transfer capability and an associated heavy-haul shipment capability (see Section 2.1.3.3.3).

Legal-weight truck shipments would use existing routes that satisfy regulations of the U.S. Department of Transportation for the shipment of highway route-controlled quantities of radioactive materials (49 CFR 397.101). Legal-weight trucks would enter Nevada on I-15 from the north or south, bypass the Las Vegas area on the proposed beltway, and travel north on U.S. 95 to the Nevada Test Site and then to the Yucca Mountain site (Figure 2-24).

2.1.3.3.2 *Nevada Rail Scenario*

Under this scenario, DOE would construct and operate a branch rail line in Nevada. Based on previous studies (described in Section 2.3.3.1), DOE has narrowed its consideration for a new branch rail line to five potential rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. These rail corridors are shown on Figure 2-26 and are described in the following paragraphs. DOE has analyzed a 0.4-kilometer (0.25-mile)-wide corridor for each alternative. As shown in Figure 2-26, there are possible corridor *variations*, which are described further in Appendix J.

- *Caliente Rail Corridor Implementing Alternative.* The Caliente corridor originates at an existing siding to the Union Pacific mainline railroad near Caliente, Nevada (Figure 2-26). Depending on the variations that DOE could use, the corridor is between 512 kilometers (318 miles) and 553 kilometers (331 miles) long from the Union Pacific line connection to the Yucca Mountain site.

- *Carlin Rail Corridor Implementing Alternative.* The Carlin corridor originates at the Union Pacific main line railroad near Beowawe in north-central Nevada (Figure 2-26). The Carlin and Caliente corridors converge near the northwest boundary of the Nellis Air Force Range (also known as the Nevada Test and Training Range). Past this point, they are identical. Depending on the variations

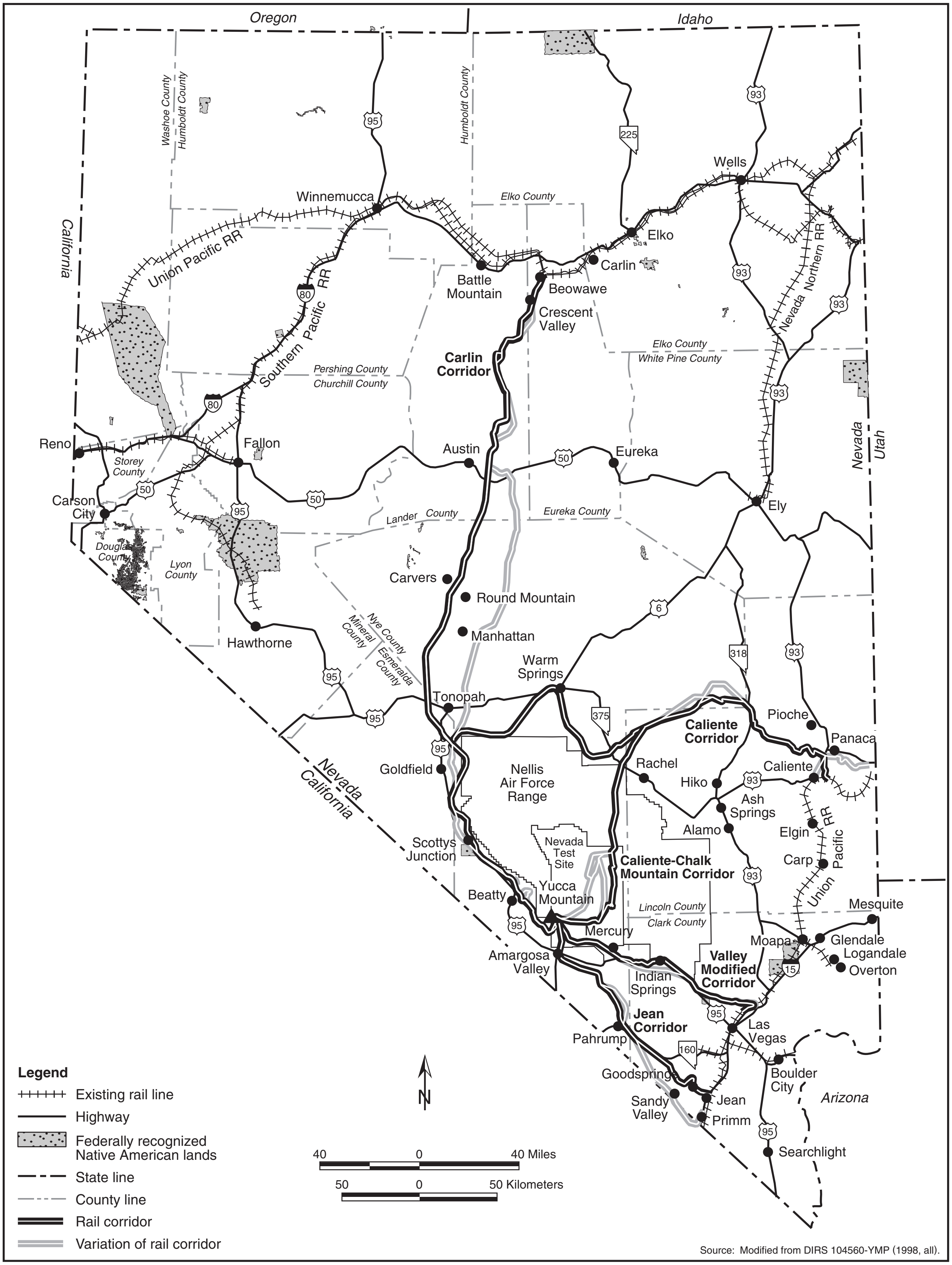


Figure 2-26. Potential Nevada rail routes to Yucca Mountain.

that DOE could use, the corridor has two major *options*—Big Smoky Valley and Monitor Valley. The Big Smoky Valley Option is between 513 kilometers (319 miles) and 529 kilometers (329 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site. Depending on the variation used, the Monitor Valley Option is between 525 kilometers (326 miles) and 544 kilometers (338 miles) long.

- *Caliente-Chalk Mountain Rail Corridor Implementing Alternative.* The Caliente-Chalk Mountain corridor is identical to the Caliente corridor until it approaches the northern boundary of the Nellis Air Force Range. At that point the Caliente-Chalk Mountain corridor turns south through the Nellis Air Force Range and the Nevada Test Site to the Yucca Mountain site (Figure 2-26). Depending on the variations that DOE could use, the corridor is between 344 kilometers (214 miles) and 382 kilometers (242 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain site.

- *Jean Rail Corridor Implementing Alternative.* The Jean corridor originates at the existing Union Pacific mainline railroad near Jean, Nevada (Figure 2-26). The corridor has two major alignment options–Wilson Pass and Stateline Pass. The Wilson Pass Option is between 181 kilometers (112 miles) and 186 kilometers (116 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain site. The Stateline Pass Option is between 198 kilometers (123 miles) and 204 kilometers (127 miles) long.

- *Valley Modified Rail Corridor Implementing Alternative.* The Valley Modified corridor originates at an existing rail siding off the Union Pacific mainline railroad northeast of Las Vegas. Depending on the variation that DOE could use, the corridor is between 157 kilometers (98 miles) and 163 kilometers (101 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site.

2.1.3.3.2.1 Rail Line Construction. The selected rail line would be designed and built in compliance with Federal Railroad Administration safety standards. In addition, a service road along the rail line would be built and maintained. Rail line construction along any of the corridors would take between 3 and 4 years. Construction would start after the selection of a route, completion of engineering and environmental studies related to alignment within the related corridor, completion of the rail line design, and land acquisition.

Construction activities would include the development of *construction support areas*; construction of access roads to the rail line construction initiation points and to major structures to be built, such as bridges; and movement of equipment to the construction initiation points. The number and location of construction initiation points would be based on such variables as the route selected, the length of the line, the construction schedule, the number of contractors used for construction, the number of structures to be built, and the locations of existing access roads adjacent to the rail line.

The construction of a rail line would require the clearing and excavation of previously undisturbed lands in the corridor and the establishment of borrow and *spoils areas* outside the corridor. To establish a stable platform for the rail track, construction crews would excavate some areas and fill (add more soil to) others, as determined by terrain features. To the extent possible, material excavated from one area would be used in areas that required fill material. However, if the distance to an area requiring fill material was excessive, the excavated material would be disposed of in adjacent low areas, and a *borrow area* would be established adjacent to the area requiring fill material. Access roads to spoils and borrow areas would be built during the track platform construction work.

Typical heavy-duty construction equipment (front-end loaders, power shovels, and other diesel-powered support equipment) would be used for clearing and excavation work. Trucks would spray water along graded areas for dust control and soil compaction. The fill material used along the rail line to establish a stable platform for the track would be compacted to meet design requirements. Water could be shipped from other locations or obtained from wells drilled along the route.

Railroad track construction would consist of the placement of railbed material, ties, rail, and ballast (support and stabilizing materials for the rail ties) over the completed railbed platform. Other activities would include the following:

- Installation of at-grade crossings (which would require rerouting existing utility lines in some areas)
- Installation of fences along the rail line, if requested by other agencies (for example, the Bureau of Land Management or the Fish and Wildlife Service)
- Installation of the train control system (monitoring equipment, signals, communications equipment)
- Final grading of slopes, installation of rock-fall protection devices, replacement of topsoil, revegetation and installation of other permanent erosion control systems, and completion of the adjacent maintenance road

2.1.3.3.2.2 Rail Line Operations. Branch rail line operations from the junction with the main line to the proposed repository at Yucca Mountain would meet Federal Railroad Administration standards for maintenance, operations, and safety. Current plans for the branch rail line anticipate a train with two 3,000-horsepower, diesel-electric locomotives; from one to five railcars containing spent nuclear fuel and high-level radioactive waste; *buffer cars*; and escort cars. Trains could also haul other freight to and from the repository site, thereby decreasing the truck traffic on local roads. The EIS analyses assumed that all repository construction materials and equipment would be transported to the Yucca Mountain site by truck.

The operational interface between the Union Pacific and the branch rail line would be determined by whether the waste was shipped to Nevada by dedicated rail service or by *general freight rail service*. With dedicated rail or general freight service to Nevada, the railcars carrying spent nuclear fuel or high-level radioactive waste could be parked on a side track (off the main rail line) at the connection point until a train could be assembled to travel to the repository site. A small secure railyard off the main rail line would be established for switching operations. Railcars with spent nuclear fuel or high-level radioactive waste would have to be moved within 48 hours in accordance with U.S. Department of Transportation regulations (49 CFR 174.14).

This EIS assumes there would be about four trains per week for shipments of spent nuclear fuel and high-level radioactive waste to the repository. In addition, the rail line would enable the transport of other material to the repository, including empty disposal containers, bulk concrete materials, steel, large equipment, and general building materials. The EIS assumes one train per week for this other material for a total of about five trains per week to the repository from about 2010 to 2033.

2.1.3.3.3 *Nevada Heavy-Haul Truck Scenario*

Under this scenario, rail shipments to Nevada would go to an intermodal transfer station where shipping casks would transfer from railcars to heavy-haul trucks. The heavy-haul trucks would travel on existing roads to the repository, once the roads were appropriately upgraded. The following sections describe the implementing alternatives (the intermodal transfer station locations and associated highway routes for heavy-haul trucks) that the EIS analyzes.

2.1.3.3.3.1 Intermodal Transfer Stations. To enable intermodal transfers and heavy-haul shipments to the repository, an intermodal transfer station would be built and operated in Nevada. DOE is considering three potential locations for intermodal transfer operations: near Caliente, northeast of Las Vegas (Apex/Dry Lake), and southwest of Las Vegas (Sloan/Jean) (Figure 2-27). DOE has identified general areas at these three locations where it could build and operate an intermodal transfer station:

- *Caliente Intermodal Transfer Station Implementing Alternative*. The Caliente siting areas are south of Caliente in the Meadow Valley Wash. DOE has identified two possible areas along the west side of the wash.

- *Apex/Dry Lake Intermodal Transfer Station Implementing Alternative*. The areas for a potential station are northeast of Las Vegas along the Union Pacific Railroad's main line at Dry Lake and Apex. Three areas are available for intermodal transfer station siting. The first area is directly adjacent to the Dry Lake siding along the west side of the Union Pacific line. The second area is smaller and lies on the same side of the tracks a short distance northeast of the first area. The third area is between Interstate 15 and the Union Pacific tracks south of where the tracks cross the Interstate. Because this area is between the Dry Lake and Apex sidings, the construction of an additional rail siding would be necessary.

- *Sloan/Jean Intermodal Transfer Station Implementing Alternative*. The potential areas for an intermodal transfer station southwest of Las Vegas are between the existing Union Pacific rail sidings at Sloan and Jean. One area is on the west side of I-15, north of the Union Pacific rail underpass at I-15. The second is south of the Sloan rail siding along the east side of the rail line. A third area is south of the second, directly north of the Jean interchange on I-15.

The intermodal transfer station would be a fenced area of about 250 meters (820 feet) by 250 meters and a rail siding that would be about 2 kilometers (1.2 miles) long (see Figure 2-28). The estimated total area occupied by the facility and support areas would be about 0.2 square kilometer (50 acres). It would include rail tracks, two shipping cask transfer cranes (one on a gantry rail, and one on a backup rubber-tired vehicle), an office building, and a maintenance and security building. It would also have connection tracks to the existing Union Pacific line and storage and transfer tracks inside the station boundary. The maintenance building would provide space for routine service and minor repairs to the heavy-haul trailers and tractors. The station would have power, water, and other services. Diesel generators would provide a backup electric power source. Construction of an intermodal transfer station would take an estimated 1.5 years.

Trains would switch from the main Union Pacific track to an existing or newly constructed passing track. The railcars carrying casks of spent nuclear fuel or high-level radioactive waste would be uncoupled from the train and switched to the intermodal transfer station track. The train would return to the main Union Pacific line. A railyard locomotive would move the cars containing the casks to the station.

The loading and unloading process would begin with the return of a heavy-haul truck from the repository. The empty cask returning from the repository would be lifted from the truck, loaded on an empty railcar, and secured. The gantry or mobile crane would then remove a loaded cask from another railcar and transfer it to the same truck, where it would be secured and inspected before shipment to the repository.

The station would accept railcars as they arrived (24 hours a day, 7 days a week), but it would normally dispatch heavy-haul trucks during early morning daylight hours on weekdays, consistent with current Nevada heavy-haul shipment practices.

Intermodal transfer station operations would not depend on whether the railcars that carried spent nuclear fuel and high-level radioactive waste arrived on dedicated or general freight trains.

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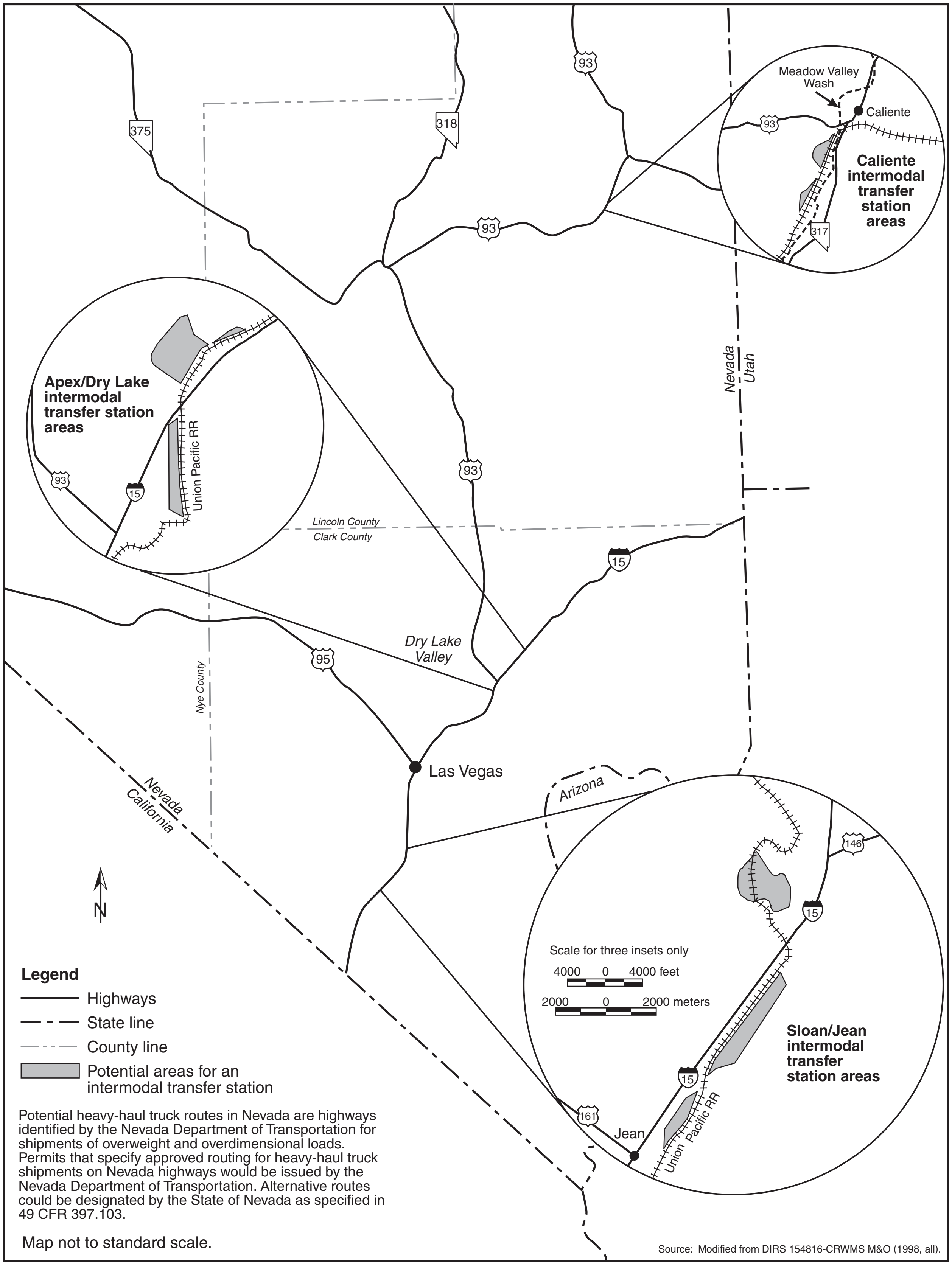

Figure 2-27. Potential intermodal transfer station locations.

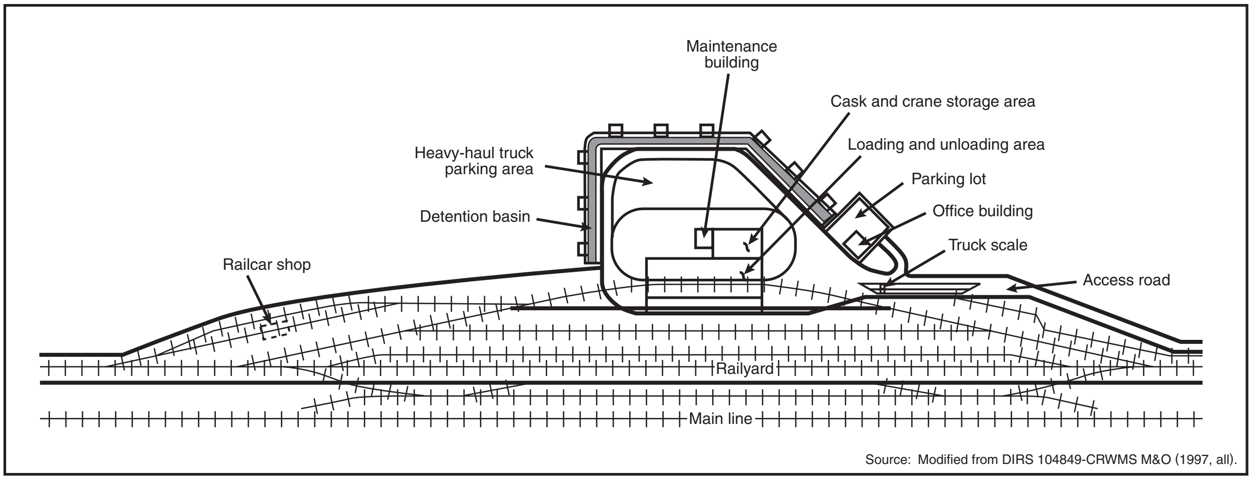

Figure 2-28. Conceptual diagram of intermodal transfer station layout.

At the completion of the 24 years of shipping, the intermodal transfer station would be decommissioned and, if possible, reused.

2.1.3.3.3.2 Highway Routes for Heavy-Haul Shipments. Figure 2-29 is an illustration of a heavy-haul truck that DOE could use to transport spent nuclear fuel and high-level radioactive waste to the repository. The heavy-haul truck would weigh about 91,000 kilograms (200,000 pounds) unloaded and would be up to 67 meters (220 feet) long. It would be custom-built for repository shipments. Typical range of open-road speeds would be 32 to 80 kilometers (20 to 50 miles) per hour.

Heavy-haul truck shipments from an intermodal transfer station to the repository would comply with U.S. Department of Transportation requirements for shipments of highway route-controlled quantities of radioactive materials (49 CFR Part 177) and with State of Nevada permit requirements for heavy-haul shipments. Nevada permits heavy-haul shipments on Monday through Friday (excluding holidays) but only in daylight hours.

Road upgrades for candidate routes, if necessary, would involve four kinds of construction activities: (1) widening the shoulders and constructing turnouts and truck lanes, (2) upgrading intersections that are inadequate for heavy-haul truck traffic, (3) increasing the asphalt thickness (overlay) of some sections, and (4) upgrading engineered structures such as culverts and bridges. The overlay work would include upgrades needed to remove frost restrictions from some road sections.

Shoulder widening and the construction of turnouts and truck lanes would occur as needed along the side of the existing pavement. Shoulders would be widened from 0.33 or 0.66 meter (1 or 2 feet) to 1.2 meters (4 feet). Widening would build the existing shoulder up to pavement height. Truck lanes would be built on roadways with grades exceeding 4 percent. Turnout lanes would be built approximately every 8 to 32 kilometers (5 to 20 miles) depending on projected traffic. The truck lanes and turnouts would require land clearing and soil excavation or fill to establish the roadway. Culverts under the roadway would be lengthened. DOE assumes that most borrow material for construction could come from existing Nevada Department of Transportation borrow areas. Asphalt could be produced at a portable plant in the borrow areas. Appendix J contains descriptions of the specific highway improvements for the five routes.

The following paragraphs describe the potential highway routes for heavy-haul trucks DOE is considering for the intermodal transfer station location and unique operational considerations for each route.

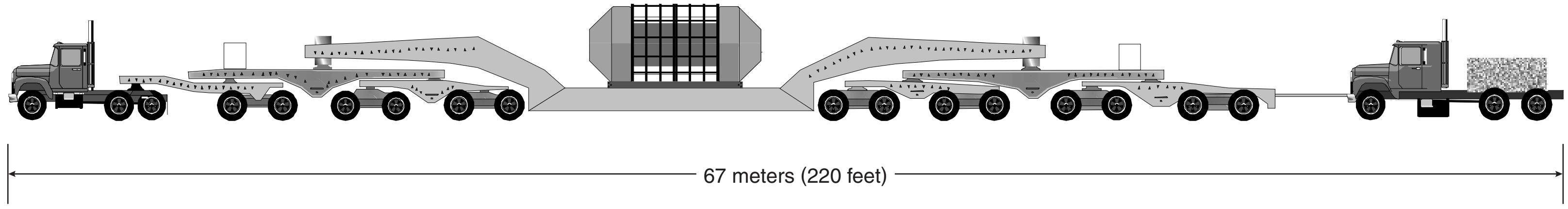

Figure 2-29. Artisit's conception of a heavy-haul truck carrying a rail shipping cask.

- *Caliente Intermodal Transfer Station Highway Routes*. Heavy-haul trucks leaving the Caliente intermodal transfer station could travel on one of three potential routes: (1) Caliente, (2) Caliente/ Chalk Mountain, and (3) Caliente/Las Vegas (see Figure 2-30).

  The Caliente route would be approximately 533 kilometers (331 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. Highway 93. The trucks would travel west on U.S. 93 to State Route 375, then on State Route 375 to the intersection with U.S. Highway 6. The trucks would continue on U.S. 6 to the intersection with U.S. 95 in Tonopah, then into Beatty on U.S. 95, where an *alternate* truck route would be built because the existing intersection is too constricted to allow a turn. Heavy-haul trucks would then travel south on U.S. 95 to the Lathrop Wells Road exit, which accesses the Yucca Mountain site. Because of the estimated travel time associated with the Caliente route and the restriction on nighttime travel for heavy-haul vehicles, DOE would construct a parking area along the route to enable these vehicles to park overnight. This parking area would be near the U.S. 6 and U.S. 95 interchange at Tonopah.

  The Caliente/Chalk Mountain route would be approximately 282 kilometers (175 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel on U.S. 93 to State Route 375, on State Route 375 to Rachel, and head south through the Nellis Air Force Range to the Nevada Test Site.

  The Caliente/Las Vegas route would be approximately 376 kilometers (234 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel south on U.S. 93 to the intersection with I-15, northeast of Las Vegas. The trucks would travel south on I-15 to the exit for the proposed northern Las Vegas Beltway, then would travel west on the beltway. They would leave the beltway at U.S. 95, and head north on U.S. 95 to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

- *Apex/Dry Lake Intermodal Transfer Station Highway Route*. Heavy-haul trucks would leave the intermodal transfer station at the Apex/Dry Lake location and enter I-15 at the Apex interchange. The trucks would travel south on I-15 to the exit to the proposed northern Las Vegas Beltway, and would travel west on the beltway. The trucks would leave the beltway at U.S. 95, and travel north on U.S. 95 to the Nevada Test Site. They would then travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. This route is about 183 kilometers (114 miles) long (see Figure 2-30).

- *Sloan/Jean Intermodal Transfer Station Highway Route*. Heavy-haul trucks leaving a Sloan/ Jean intermodal transfer station would enter I-15 at the Sloan interchange. The trucks would travel on I-15 to the exit to the southern portion of the proposed Las Vegas Beltway, and then travel northwest on the beltway. They would leave the beltway at U.S. 95, and travel to the Nevada Test Site. They would then travel on Jackass Flats Road to the Yucca Mountain site. This route would be approximately 190 kilometers (118 miles) long (see Figure 2-30).

2.1.3.4 Shipping Cask Manufacturing, Maintenance, and Disposal

To transport spent nuclear fuel and high-level radioactive waste to the repository, DOE would use existing or new shipping casks that met Nuclear Regulatory Commission regulations (10 CFR Part 71). One or more qualified companies that provide specialized metal structures, tanks, and other heavy equipment would manufacture new shipping casks. The number and type of shipping casks required would depend on the predominant mode of transportation.

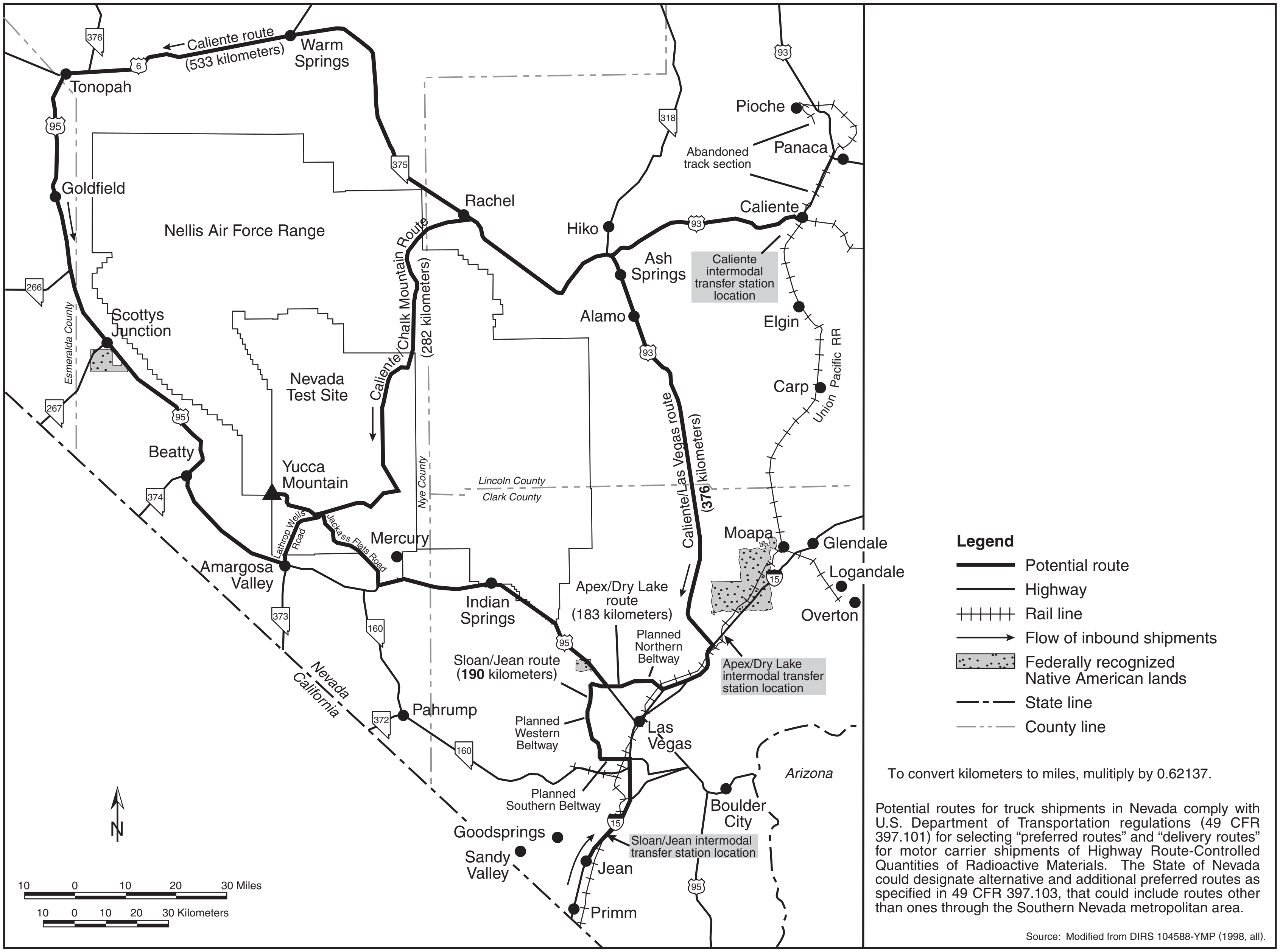

Figure 2-30. Potential routes in Nevada for heavy-haul trucks.

DOE would remove casks from service periodically for maintenance and inspection. These activities would occur at a cask maintenance facility(s) where cask functions and components would be checked and inspected in compliance with Nuclear Regulatory Commission requirements and preventive maintenance procedures. The major operations involved in cask maintenance would include decontamination, replacement of limited-life components such as O-rings, and verification of radiation *shielding* integrity, structural integrity, and heat transfer efficiency.

The large number of repository shipments would require new facilities for cask maintenance. DOE has not decided where in the United States it would locate a cask maintenance facility(s), but this EIS assumes that such a facility would be at the repository inside the Restricted Area at the North Portal on approximately 0.01 square kilometer (2.5 acres). Minor cask maintenance activities could occur at commercial or DOE sites.

2.1.4 ALTERNATIVE DESIGN CONCEPTS AND DESIGN FEATURES

DOE used the preliminary design concept in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998, all), referred to as the Viability Assessment reference design, to evaluate impacts in the Draft EIS. While it was preparing the Draft EIS, DOE considered a broad range of design features and alternatives that would enhance the VA reference design within the License Application Design Selection process (DIRS 107292-CRWMS M&O 1999, all). In addition, the features and alternatives were combined into groups called *enhanced design alternatives*, each of which defined a unique design concept for the repository. DOE anticipated choosing an enhanced design alternative that it could carry forward to the licensing process.

The final *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all) recommended Enhanced *Design Alternative* II (EDA II) to carry forward in the design evolution. However, DOE did specify that backfill should be only a possible option in EDA II. Accordingly, DOE adopted EDA II without backfill as the design to be evaluated for the purpose of making a determination on site recommendation, as documented in the Science and Engineering Report (DIRS 153849-DOE 2001, all). EDA II without backfill, over a range of thermal operating modes, was evaluated in the Supplement to the Draft EIS and is also the basis for this Final EIS.

The following section qualitatively discusses potential future design features and alternatives. Appendix E provides further detail on alternative design concepts and alternatives and their potential environmental impacts.

2.1.4.1 Design Features and Alternatives To Control the Thermal/Moisture Environment in the Repository and To Limit Release and Transport of Radionuclides

Through successive evaluations and improvements, the repository design has evolved to the flexible design. This represents the current state of the ongoing process that identifies and develops ideas through conceptual, then preliminary, then more detailed designs to produce a design that DOE would use for purposes of the Secretary of Energy’s determination of whether to recommend approval of the Yucca Mountain site to the President for development of a geologic repository. Coupled with information from ongoing scientific tests and investigations, the design process continues to provide insights into how to improve repository performance and reduce uncertainties in performance projections.

A key to the determination on site recommendation is demonstrating whether a repository at Yucca Mountain would be likely to meet regulatory standards. To that end, scientific tests and studies identify and quantify uncertainties in performance assessment and confirm performance projections. Due to limitations in the understanding of natural processes that might occur over thousands of years, as well as the limits on being able to characterize the site fully, uncertainties in performance assessments can never be completely eliminated. DOE believes that the natural system and the robust flexible design would accommodate unquantified and residual uncertainties through performance margin (design and safety) and defense-in-depth. *Defense-in-depth* is a design approach that relies on a series of barriers, both natural and manmade, that would work in a complementary manner to minimize the amount of radioactive material that could eventually travel from the repository to the human environment.

Refining details of the design of the proposed repository is an ongoing and progressive process [see the Science and Engineering Report (DIRS 153849-DOE 2001, Section 2.1.2)]. As more information becomes available about the site, along with results from tests to evaluate the implementation of the design, DOE will continue to refine the repository design. To increase the level of confidence in the understanding of long-term repository behavior, scientific tests would continue throughout the periods before and during License Application (if the site was recommended and approved for development as a repository), construction authorization, repository operations, and performance monitoring. With the flexibility inherent in the design, periodic reviews of the results of the ongoing testing program and other design activities could prompt further design feature modifications.

As described in this chapter, DOE is considering a number of scenarios and operating modes, which are defined by key parameters that include the number of waste packages, spacing between waste packages, whether there would be surface aging, average linear thermal load, average maximum waste package temperature, emplacement period, emplacement area, length of emplacement and access drifts (as well as total excavated volume), drift spacing, and ventilation (forced-air and natural).

As an example of ongoing studies, DOE is examining the use of an extended period of natural ventilation of emplacement drifts after a period of forced-air ventilation. The heat generated by the spent nuclear fuel and high-level radioactive waste could develop and maintain a temperature difference to drive passive ventilation of the emplacement drifts throughout the maximum time the repository would remain open. The heat from the waste could be used to draw cooler, drier external air through the intake shafts, across the emplacement drifts, and out the exhaust shafts (located at an elevation above the intakes), much the way heat from a fireplace draws air from a room and exhausts it through a chimney. Passive ventilation is used to regulate air temperature in buildings and has similar uses in large subsurface structures such as mines. Findings in numerous caves that are analogous to a deep geologic repository (DIRS 153849-DOE 2001, Section 2.1.5.4) support the idea that the environment of a naturally ventilated underground system could, under certain conditions, preserve materials for several thousand years and could greatly reduce waste package degradation. Optimizing the repository design to accommodate natural ventilation could result in a reconfigured supply and exhaust scheme, additional shafts, and air control devices for the drifts. Changes at the surface would include additional Ventilation Shaft Operations Areas associated with ventilation and exhaust shafts, as well as access roads to the additional shaft locations.

Drift spacing could be greater or smaller than that presented for the analytical scenarios, and could influence the size of the emplacement area and the length of emplacement and access drifts, as well as the total excavated underground volume (see DIRS 153849-DOE 2001, Section 2.1.4). Drift spacing versus waste package spacing is a design trade-off to achieve lower heat output per unit volume of a repository. The effect of drift spacing on these related parameters would be less than the effect of waste package spacing in the analytical scenarios discussed in this EIS. Therefore, DOE did not perform a *quantitative* evaluation of the environmental impacts of variable drift spacing.

2.1.4.2 Design Features and Alternatives to Support Operational and Cost Considerations

Uncertainties in future funding profiles or the order of spent nuclear fuel or high-level radioactive waste shipments could result in development of the repository in a sequential or modular manner (that is,

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constructing the surface and subsurface facilities in portions, or "modules"). This approach would facilitate the ability to incorporate "lessons learned" from initial work into subsequent modules, reduce initial construction costs and investment risk, and potentially increase confidence in meeting the schedule for waste receipt and emplacement. DOE has requested that the National Research Council continue the study of possible repository development strategies (DIRS 153849-DOE 2001, Section 2.1.3).

2.1.5 ESTIMATED COSTS ASSOCIATED WITH THE PROPOSED ACTION

DOE has estimated the total cost of the Proposed Action to construct, operate and monitor, and close a geologic repository at Yucca Mountain, including the transportation of spent nuclear fuel and high-level radioactive waste to the repository (DIRS 156900-DOE 2001, all). The estimate is based on acceptance and disposal of about 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, and 8,315 canisters of solidified high-level radioactive waste (4,667 MTHM). Table 2-5 lists the estimated costs. The total future costs from 2002 to closure for the flexible design would range from about $42.7 to $57.3 billion (in 2001 dollars). DOE is reporting future costs for comparison with the No-Action Alternative. Historical costs through 2001 are $8.8 billion (in 2001 dollars). The costs are representative and would vary somewhat, depending on the operating mode, packaging and transportation scenarios, and the Nevada transportation implementing alternative selected.

Table 2-5. Proposed Action costs from 2002 to closure.[a,b]

Description	Operating mode	
	Higher-temperature	Lower-temperature
Monitored geologic repository	31.5	37.4 - 43.1
Waste acceptance, storage, and transportation	4.3	4.3
Nevada transportation	0.8	0.8
Program integration	2.2	2.4 - 3.7
Institutional	3.9	4.1 - 5.4
Total	***$42.7***	***$49.0 - 57.3***

a. Source: DIRS 156900-DOE (2001, all).
b. Adjusted to 2001 dollars, in billions per DIRS 156899-DOE (2001, Appendix A).

The activities comprising the cost elements, Monitored Geologic Repository; Waste Acceptance, Storage and Transportation; and Nevada Transportation in Table 2-5 are described in this EIS. The last two elements are Program Integration and Institutional. Program Integration includes Quality Assurance (which is a mandatory program to identify and ensure implementation of requirements that protect the health and safety of the public, workers, and environment), Program Management and Integration, and non-Office of Civilian Radioactive Waste Management costs associated with the NRC, Nuclear Waste Technical Review Board, and the Nuclear Waste Negotiator. Institutional includes financial assistance for transportation planning. Details about the estimated costs are in *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program* (DIRS 153255-DOE 2001, all) and *Life Cycle Cost Analysis for Repository Flexible Design Concepts* (DIRS 156900-DOE 2001, all). These reports provide further information on the basis of the estimates, time phasing of the expected expenditures, and the subdivision of the costs between the major activities noted in Table 2-5. For example, the cost to engineer and construct the repository would be approximately equivalent to the estimated program costs from 2002 to 2010 (proposed repository opening), or $8.3 to $9.1 billion (in 2001 dollars).

The most recent estimates show that approximately 70 percent of the repository-related costs would be paid from the Nuclear Waste Fund (fees collected by nuclear utilities from ratepayers) and about 30 percent from taxpayer revenues (primarily to pay for disposal of DOE spent nuclear fuel and high-level radioactive waste).

2.2 No-Action Alternative

This section describes the No-Action Alternative, which provides a basis for comparison with the Proposed Action. Under the No-Action Alternative, and consistent with the Nuclear Waste Policy Act, as amended [Section 113(c)(3) (the EIS refers to the amended Act as the NWPA)], DOE would terminate activities at Yucca Mountain and undertake site reclamation to mitigate any significant adverse environmental impacts. Commercial nuclear power utilities and DOE would continue to manage spent nuclear fuel and high-level radioactive waste at 77 sites in the United States (see Figure 2-31).

In addition, DOE would prepare a report to Congress with the Department's recommendations for further action to ensure the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. Under any future course that would include continued storage at the generator sites, commercial utilities and DOE would have to continue managing spent nuclear fuel and high-level radioactive waste in a manner that protected public health and safety and the environment. However, the future course that Congress, DOE, and the commercial utilities would take if Yucca Mountain were not recommended as a repository remains uncertain. DOE recognizes that a number of possibilities could be pursued, including continued storage of spent nuclear fuel and high-level radioactive waste at one or more centralized locations, study and selection of another location for a deep geologic repository (Chapter 1 identifies the process and alternative sites previously selected by DOE for technical study as potential geologic repository locations), the development of new technologies (for example, transmutation), or reconsideration of alternatives to geologic disposal. The environmental considerations of these possibilities have been analyzed in other contexts in other documents to varying degrees.

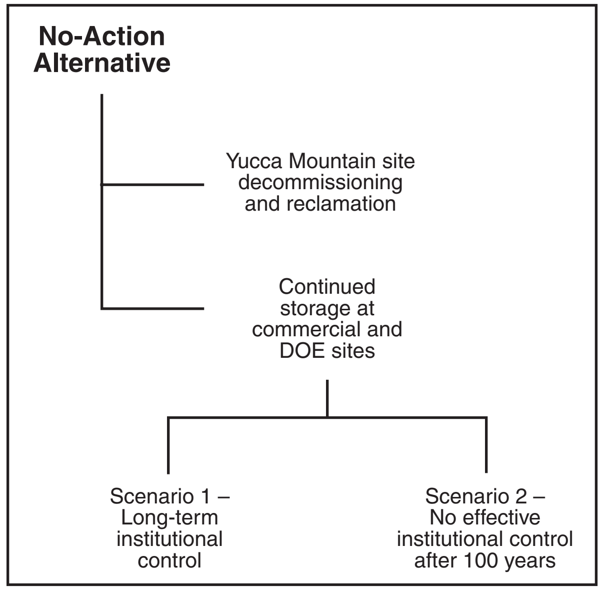


Figure 2-31. No-Action Alternative activities and analytical scenarios.

The No-Action Alternative did not consider redistribution or centralizing of spent nuclear fuel. However, Table 7-1 lists several references to documents that have evaluated potential environmental impacts of away-from-reactor spent nuclear fuel consolidation facilities. In addition, because the Department believes that it is a reasonably foreseeable future action, the Final EIS includes an evaluation of potential cumulative transportation impacts associated with the shipment of 40,000 metric tons of heavy metal of commercial spent nuclear fuel to a proposed privately owned centralized storage facility at Skull Valley in Utah (see Section 8.4 for details).

In light of the uncertainties described above, DOE decided to illustrate the possibilities by focusing the analysis of the No-Action Alternative on the potential impacts of two scenarios:

- Long-term storage of spent nuclear fuel and high-level radioactive waste at the current sites with effective institutional control for at least 10,000 years (Scenario 1)

- Long-term storage at the current storage sites with no effective institutional control after about 100 years (Scenario 2)

Although these scenarios would be unlikely, they provide a basis for comparison to the impacts of the Proposed Action and they reflect a range of impacts that could occur.

The following sections describe expected Yucca Mountain site decommissioning and reclamation activities (Section 2.2.1), and further describe the scenarios for continued spent nuclear fuel and high-level radioactive waste management at the commercial and DOE sites (Section 2.2.2). Chapter 7 describes the potential environmental impacts of the No-Action Alternative.

2.2.1 YUCCA MOUNTAIN SITE DECOMMISSIONING AND RECLAMATION

Under the No-Action Alternative, site characterization activities would end at Yucca Mountain and decommissioning and reclamation would begin as soon as practicable and could take several years to complete. Decommissioning and reclamation would include removing or shutting down surface and subsurface facilities, and restoring lands disturbed during site characterization.

Portable and prefabricated buildings would be emptied of their contents, dismantled, and removed from the site. Other facilities could be shut down without being removed from the site. DOE would remove and salvage such equipment as electric generators and tunneling, ventilation, meteorological, and communications equipment. Foundations and similar materials would remain in place.

DOE would remove equipment and materials from the underground drifts and test rooms. Horizontal and vertical drill holes extending from the subsurface would be sealed. Subsurface drifts and rooms would not be backfilled, but would be left with the steel inverts in place. The North and South Portals would be gated to prohibit entry to the subsurface.

Excavated rock piles would be stabilized. Topsoil previously removed from the excavated rock pile area and stored in a stockpile would be returned and the areas would be revegetated. Areas disturbed by surface studies (drilling, trenching, *fault* mapping) or used during site characterization (borrow areas, laydown pads, etc.) would be restored. Fluid impoundments (mud pits, evaporation ponds) would be backfilled or capped as appropriate and reclaimed. Access roads throughout the site (paved or graveled) and parking areas would be left in place and would not be restored.

2.2.2 CONTINUED STORAGE OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT COMMERCIAL AND DOE SITES

Under the No-Action Alternative, spent nuclear fuel and high-level radioactive waste would be managed at the 72 commercial and 5 DOE sites (the Hanford Site, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, Fort St. Vrain, and the West Valley Demonstration Project) (see Figure 1-1). The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would be treated, packaged, and stored. The amount of spent nuclear fuel and high-level radioactive waste considered in this analysis is the same as that in the Proposed Action—70,000 MTHM, including 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, and 8,315 canisters of solidified high-level radioactive waste (4,667 MTHM). This EIS assumes that the No-Action Alternative would start in 2002.

2.2.2.1 Storage Packages and Facilities at Commercial and DOE Sites

A number of designs for storage packages and facilities at the commercial and DOE sites would provide adequate protection to the environment from spent nuclear fuel and high-level radioactive waste. Because specific designs have not been identified for most locations, DOE selected a representative range of commercial and DOE designs for analysis as described in the following paragraphs.

Spent Nuclear Fuel Storage Facilities

Most commercial nuclear utilities currently store their spent nuclear fuel in water-filled basins (fuel pools) at the reactor site. Some utilities have built *independent spent fuel storage installations* in which they store spent nuclear fuel dry, above ground, in metal casks or in weld-sealed canisters inside reinforced concrete storage modules. Some utilities are planning to build independent spent fuel storage installations so they can proceed with decommissioning their nuclear plants and terminating their operating licenses (for example, the Rancho Seco and Trojan plants). Because utilities could elect to continue operations until their fuel pools are full and then cease operations, the EIS analysis originally considered ongoing wet storage in existing fuel pools to be a potentially viable option for spent nuclear fuel storage. However, dry storage is the preferred option for long-term spent nuclear fuel storage at commercial sites for the following reasons (DIRS 101899-NRC 1996, pp. 6-76 and 6-85):

- Dry storage is a safe economical method of storage.
- Fuel rods in dry storage are likely to be environmentally secure for long periods.
- Dry storage generates minimal, if any, amounts of low-level radioactive waste.
- Dry storage units are simpler and easier to maintain.

Accordingly, this EIS assumes that all commercial spent nuclear fuel would be in dry storage at independent spent fuel storage installations at existing locations. This includes spent nuclear fuel at sites that no longer have operating nuclear reactors. Figure 2-32 shows a photograph of a typical independent spent fuel storage installation at a commercial nuclear site. Although most utilities and DOE have not constructed independent spent fuel storage installations or designed dry storage containers, this analysis evaluated the impacts of storing all commercial and most DOE spent nuclear fuel in horizontal concrete storage modules (see Figure 2-33) on a concrete pad at the ground surface. Concrete storage modules have openings that allow outside air to circulate and remove the heat of radioactive decay. The analysis assumed that both pressurized-water reactor and *boiling-water reactor* spent nuclear fuel would have been loaded into a dry storage canister that would be placed inside the concrete storage module. Figure 2-34 shows a typical dry storage canister, which would consist of a stainless-steel outer shell, welded end plugs, pressurized helium internal environment, and criticality-safe geometry for 24 pressurized-water or 52 boiling-water reactor fuel assemblies.

The combination of the dry storage canister and the concrete storage module would provide safe storage of spent nuclear fuel as long as the fuel and storage facilities were properly maintained. The reinforced concrete storage module would provide shielding against the radiation emitted by the spent nuclear fuel. The concrete storage module would also provide protection from damage from such occurrences as aircraft crashes, earthquakes, and tornadoes.

This analysis assumed that DOE spent nuclear fuel at the Savannah River Site, Idaho National Engineering and Environmental Laboratory, and Fort St. Vrain would be stored dry, above ground in stainless-steel canisters inside concrete casks. In addition, it assumed that the design of DOE above-ground spent nuclear fuel storage facilities would be similar to the independent spent fuel storage installations at commercial nuclear sites.

The analysis assumed that DOE spent nuclear fuel at Hanford would be stored dry in below-grade storage facilities. The Hanford N-Reactor fuel would be stored in the Canister Storage Building, which would consist of three below-grade concrete vaults with air plenums for natural convective cooling. Storage tubes of *carbon steel* would be installed vertically in the vaults. Each storage tube, which would be able to accommodate two spent nuclear fuel canisters, would be closed and sealed with a shield plug. The vaults would be covered by a structural steel shelter.

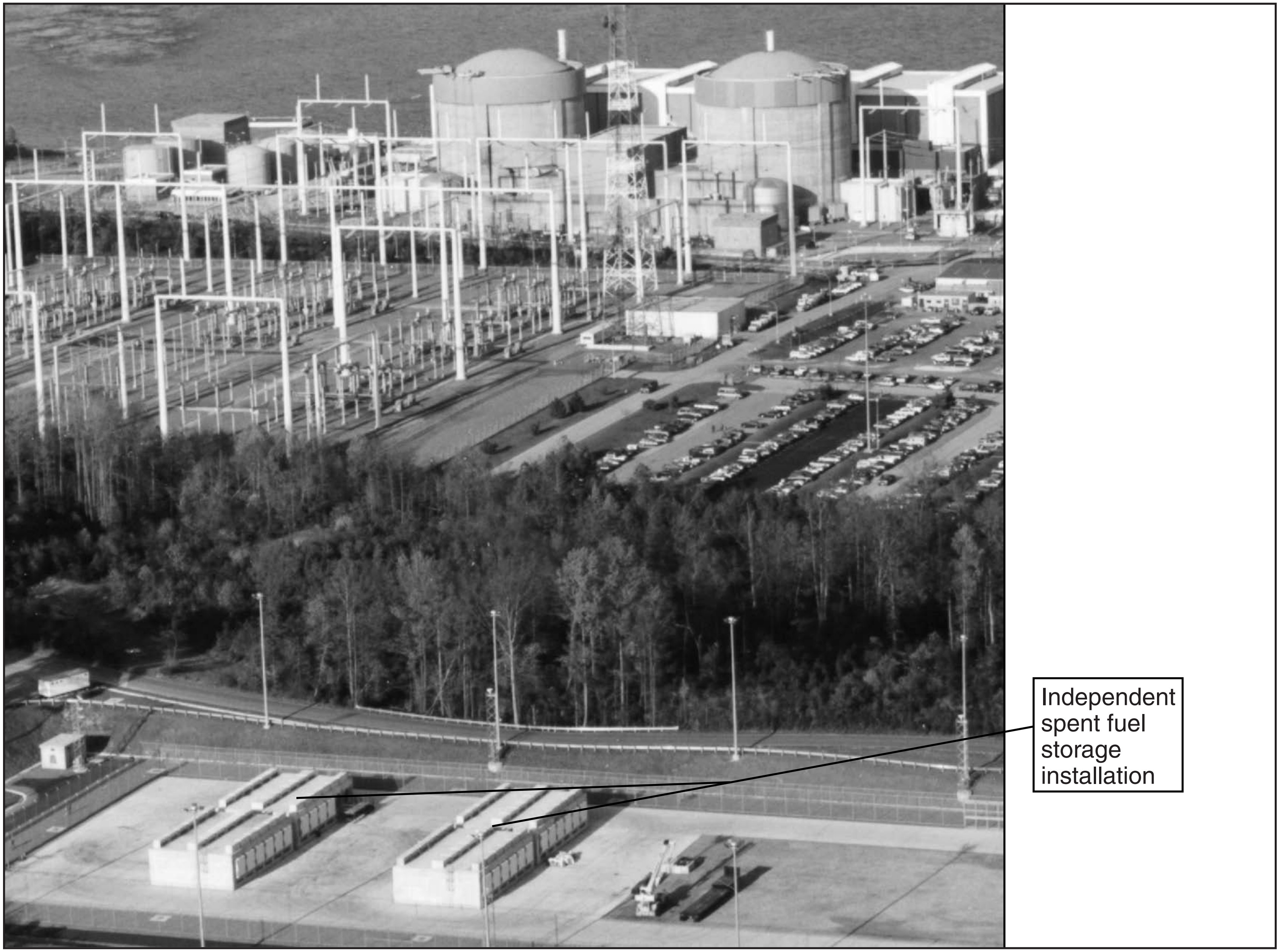


Figure 2-32. Typical independent spent fuel storage installation.

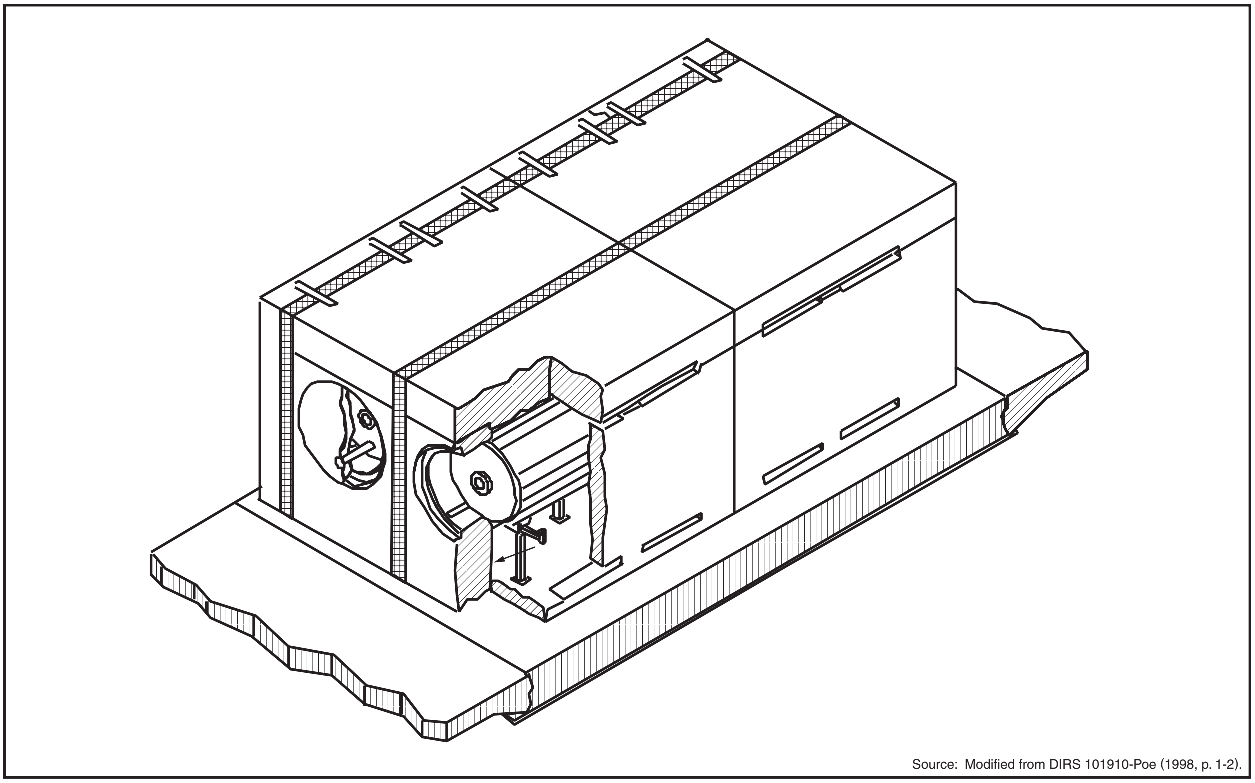


Figure 2-33. Spent nuclear fuel concrete storage module.

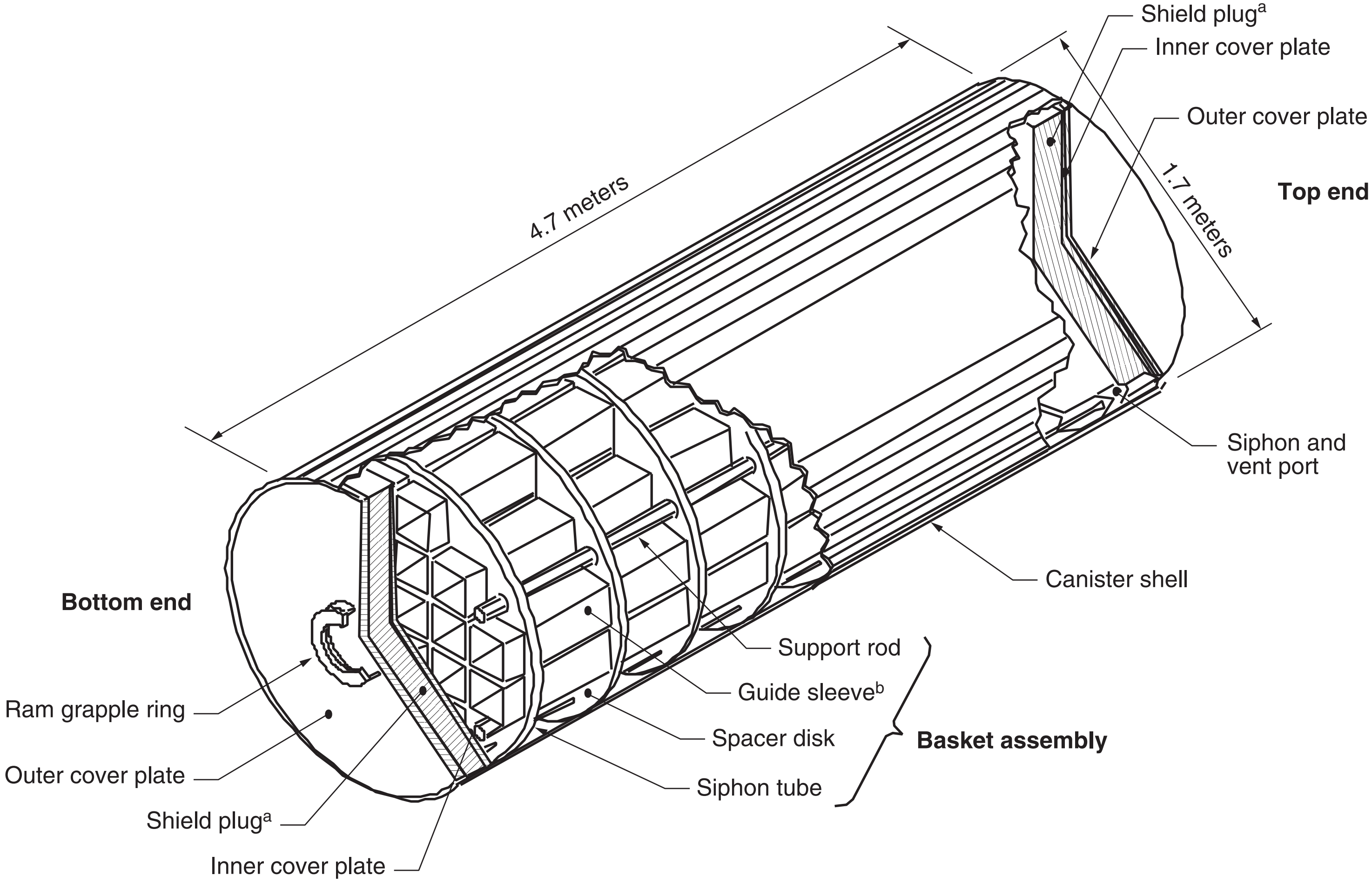
High-Level Radioactive Waste Storage Facilities

With one exception, this analysis assumed that high-level radioactive waste would be stored in a below-grade solidified high-level radioactive waste storage facility (Figure 2-35). At the West Valley Demonstration Project, it was assumed that DOE would use a dry storage system similar to a commercial spent nuclear fuel storage installation for high-level radioactive waste storage.

The high-level radioactive waste storage facility has four areas: below-grade storage vaults, an operating area above the vaults, air inlet shafts, and air exhaust shafts. The canister cavities are galvanized-steel large-diameter pipe sections arranged in a grid. Canister casings are supported by a concrete base mat. Space between the pipes is filled with overlapping horizontally stepped steel plates that direct most of the ventilation air through the storage cavities.

The below-grade storage vault would be below the operating floor, which would be slightly above grade. The storage vault would be designed to withstand earthquakes and tornadoes. In addition, the operating area would be enclosed by a metal building, which would provide weather protection and prevent the infiltration of precipitation. The storage vault would be designed to store the canisters and protect the operating personnel, the public, and the environment as long as the facilities were maintained. Radiation shielding would be provided by the surrounding earth, concrete walls, and a concrete deck that would form the floor of the operating area. Canister cavities would have individual precast concrete plugs.

Each vault would have an air inlet, air exhaust, and air passage cells. The heat of radioactive decay would be removed from around the canisters by the facility's forced air exhaust system. The exhaust air could be filtered with high-efficiency particulate air filters before it was discharged to the atmosphere through a stack, or natural *convection* cooling could be used with no filter. The oversize diameter of the pipe storage cavities would allow air passage around each cavity.



All materials 304 stainless steel except as noted.

a. Shield plug would be lead.

b. Borated neutron absorber plate
for boiling-water reactor spent nuclear fuel assemblies.

To convert meters to feet, multiply by 3.2808.

Source: Modified from DIRS 101910-Poe (1998, p. 1-5).

Figure 2-34. Spent nuclear fuel dry storage canister.

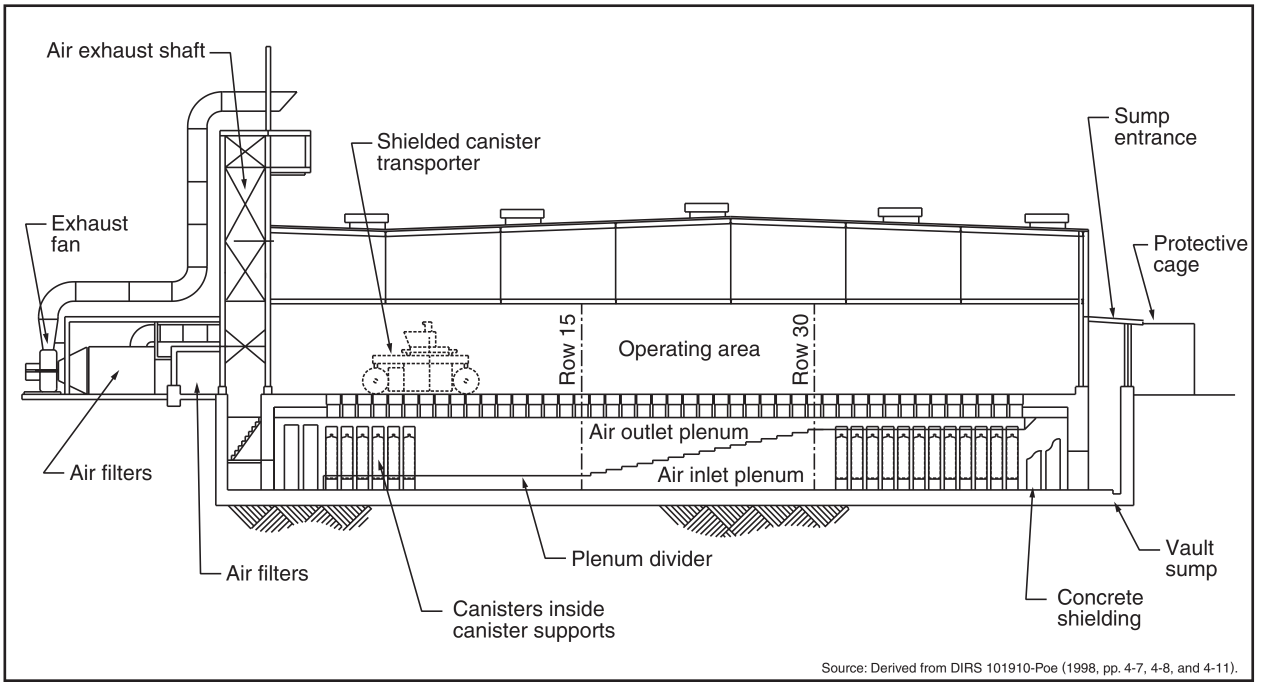


Figure 2-35. Conceptual design for solidified high-level radioactive waste storage facility.

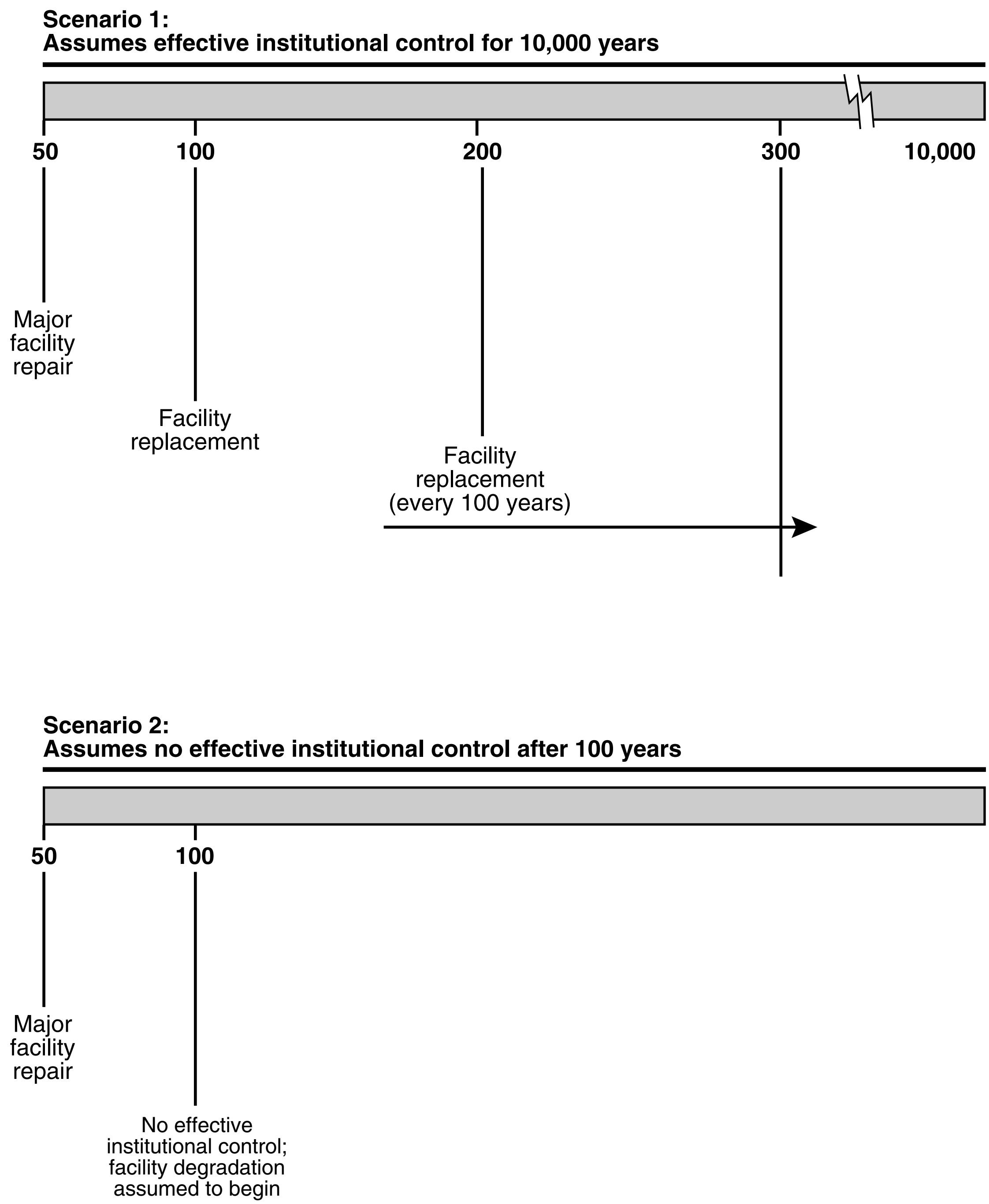
2.2.2.2 No-Action Scenario 1

In No-Action Scenario 1, DOE would continue to manage its spent nuclear fuel and high-level radioactive waste in above- or below-grade dry storage facilities at five sites around the country. Commercial utilities would continue to manage their spent nuclear fuel at 72 sites. The commercial and DOE sites would remain under effective institutional control for at least 10,000 years. Under institutional control, these facilities would be maintained to ensure that workers and the public were protected adequately in accordance with current Federal regulations (10 CFR Parts 20 and 835) and the requirements in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. DOE based the 10,000-year analysis period on the generally applicable Environmental Protection Agency regulation for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191), even though the regulation would not apply to disposal at Yucca Mountain.

Under Scenario 1, the storage facilities would be completely replaced every 100 years. They would undergo one major repair during the first 100 years, because this scenario assumes that the design of the first storage facilities at a site would include a facility life of less than 100 years. The 100-year lifespan of future storage facilities is based on analysis of concrete degradation and failure in regions throughout the United States (DIRS 101910-Poe 1998, all). The facility replacement period of 100 years represents the assumed useful lifetime of the structures. Replacement facilities would be built on land adjacent to the existing facilities. After the spent nuclear fuel and high-level radioactive waste had been transferred to the replacement facility, the older facility would be demolished and the land prepared for the next replacement facility, thereby minimizing land-use impacts. The top portion of Figure 2-36 shows the conceptual timeline for activities at the storage facilities for Scenario 1. Only the relative periods shown on this figure, not the exact dates, are important to the analysis.

2.2.2.3 No-Action Scenario 2

In No-Action Scenario 2, spent nuclear fuel and high-level radioactive waste would remain in dry storage at commercial and DOE sites and would be under effective institutional control for approximately



Timelines are approximate and for illustration only.

Figure 2-36. Facility timeline assumptions for No-Action Scenarios 1 and 2.

100 years (the same as Scenario 1). Beyond that time, the scenario assumes no effective institutional control. Therefore, after about 100 years and up to 10,000 years, the analysis assumed that the spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate and that the radioactive materials in them could eventually be released to the environment. DOE based the choice of 100 years on a review of generally applicable Environmental Protection Agency regulations for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191, Subpart B), Nuclear Regulatory Commission regulations for the disposal of low-level radioactive material (10 CFR Part 61), and a National Research Council report on standards for the proposed Yucca Mountain Repository that generally discounts the consideration of institutional control for longer periods in performance assessments for geologic repositories (DIRS 100018-National Research Council 1995, Chapter 4). The lower portion of Figure 2-36 shows the conceptual timeline for activities at the storage facilities for Scenario 2.

2.2.3 NO-ACTION ALTERNATIVE COSTS

The total estimated cost of the No-Action Alternative includes costs for the decommissioning and reclamation of the Yucca Mountain site, and for the storage of spent nuclear fuel at 72 commercial sites (63,000 MTHM), storage of DOE spent nuclear fuel (2,333 MTHM) at 4 sites (there would be no spent nuclear fuel at the West Valley Demonstration Project), and storage of solidified high-level radioactive waste (8,315 canisters) at 4 sites (there is no high-level radioactive waste at Fort St. Vrain). As listed in Table 2-6, the estimated cost (in 2001 dollars) of both Scenarios 1 and 2 for the first 100 years ranges from $55.7 billion to $61.3 billion, depending on whether the dry storage canisters had to be replaced every 100 years. The estimated costs (in 2001 dollars) for the remaining 9,900 years of Scenario 1 range from $519 million to $572 million per year. There would be no costs for Scenario 2 after the first 100 years because the scenario assumes no effective institutional control.

Table 2-6. No-Action Alternative life-cycle costs (starting in 2002) for 10,000 years (in billions of 2001 dollars).[a,b]

Factor	First 100 years	Remaining 9,900 years (per year)	
	Scenarios 1 and 2[c]	Scenario 1[c,d]	Scenario 2[e]
72 commercial sites (63,000 MTHM)	$43.6 - 49.2	$0.407 - 0.460	$0
DOE spent nuclear fuel storage sites (2,333 MTHM)	8.0	0.075	0
High-level radioactive waste storage sites (8,315 canisters)	4.1	0.038	0
Decommissioning and reclamation of the Yucca Mountain site	(f)	NA[g]	0
Totals	***$55.7 - 61.3***	***$0.519 - 0.572***	***$0***

a. Source: Adapted from DIRS 155929-Jason (1999, all).
b. Adjusted to 2001 dollars, in billions per DIRS 156899-DOE (2001, all).
c. The range of costs for commercial sites is based on the assumption that the spent nuclear fuel would either be placed in dry storage canisters that would not need to be replaced over the 10,000-year period (low cost) or would have to be placed in new dry storage canisters every 100 years (high cost).
d. Stewardship costs are expressed in average annual disbursement costs (year 2001 dollars) only.
e. Costs are not applicable.
f. The costs for decommissioning and reclamation of the Yucca Mountain site would contribute less than 0.1 percent to the total life-cycle cost of continued storage.
g. NA = not applicable.

2.3 Alternatives Considered but Eliminated from Detailed Study

This section addresses alternatives that DOE considered but eliminated from detailed study in this EIS. These include alternatives that the NWPA states this EIS need not consider (Section 2.3.1); design alternatives that DOE considered but eliminated during the evolution of the repository design analyzed in this EIS (Section 2.3.2); and alternative rail corridors and highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated during the transportation studies that identified the 10 Nevada implementing rail and intermodal alternatives analyzed in this EIS (Section 2.3.3).

2.3.1 ALTERNATIVES ADDRESSED UNDER THE NUCLEAR WASTE POLICY ACT

The NWPA states that, with respect to the requirements imposed by the National Environmental Policy Act, compliance with the procedures and requirements of the NWPA shall be deemed adequate consideration of the need for a repository, the time of the initial availability of a repository, and all alternatives to the isolation of spent nuclear fuel and high-level radioactive waste in a repository [Section 114(f)(2)]. The geologic disposal of radioactive waste has been the focus of scientific research for more than 40 years. Starting in the 1950s, the Atomic Energy Commission and the Energy Research and Development Administration (both predecessor agencies to DOE) investigated different geologic formations as potential hosts for repositories and considered different disposal concepts, including deep-seabed disposal, disposal in the polar ice sheets, and rocketing waste into the sun. After extensive discussion of the options in an EIS (DIRS 104832-DOE 1980, all), DOE decided in 1981 to pursue disposal in an underground mined geologic repository (46 *FR* 26677; May 14, 1981). A panel of the National Academy of Sciences noted in 1990 that there is a worldwide scientific consensus that deep geologic disposal, the approach being followed by the United States, is the best option for disposing of high-level radioactive waste (DIRS 100061-National Research Council 1990, all).

Chapter 1 of this EIS summarizes the process that led to the 1987 amendments to the Nuclear Waste Policy Act of 1982, in which Congress directed DOE to study only Yucca Mountain to determine if it is suitable for a repository. Consistent with this approach, the NWPA states that, for purposes of complying with the requirements of the National Environmental Policy Act, DOE need not consider alternative sites to Yucca Mountain for the repository [Section 114(f)(3)].

Under the Proposed Action, this EIS does not consider alternatives for the emplacement of more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain because the NWPA prohibits the Nuclear Regulatory Commission from approving the emplacement in the first repository of a quantity of spent nuclear fuel containing more than 70,000 MTHM or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent nuclear fuel until a second repository is in operation [Section 114(d)]. However, Chapter 8 of this EIS analyzes the cumulative impacts from the disposal of all projected spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in the proposed Yucca Mountain Repository.

2.3.2 REPOSITORY DESIGN ALTERNATIVES ELIMINATED FROM DETAILED STUDY

The preliminary design concept for the proposed Yucca Mountain Repository analyzed in this EIS is the result of a design process that began with early site characterization activities. The design process identified design alternatives (options) that DOE considered. Some of the design options were eliminated from further detailed study during the design evolution. Examples include placement of the emplacement drifts in the *saturated zone* (rather than the *unsaturated zone*); vertical shafts (rather than the gently sloping North and South Ramps); use of drilling and blasting methods for emplacement drift construction (rather than mechanical excavation methods such as tunnel-boring machines); and use of diesel-powered vehicles for waste package emplacement (rather than electrically powered, rail-based vehicles).

DOE recently undertook a comprehensive review and examination of possible design options to provide information for use in support of the suitability recommendation and License Application. Appendix E discusses the design options that DOE considered in this review, and Section 2.1.1.5 discusses their consideration in this EIS.

2.3.3 TRANSPORTATION ALTERNATIVES ELIMINATED FROM DETAILED STUDY

The transportation modes and scenarios analyzed in the EIS are based on DOE's assessment of what would be most feasible and practical for delivering spent nuclear fuel and high-level radioactive waste from generator sites across the continental United States to a repository at Yucca Mountain.

In response to public comments on the Draft EIS, DOE has evaluated the potential for including a large-scale barge scenario and a different mostly rail scenario in which railcars would be used to transport truck casks containing spent nuclear fuel and high-level radioactive waste. The purported advantage of large-scale use of barge transportation was that it would reduce the amount of cross-country overland travel that would be required. However, DOE eliminated the barge modal scenario from further consideration in the EIS because it would be overly complex, requiring greater logistical complexity than either rail or legal-weight truck transportation; a much greater number of large rail casks than rail transport; much greater cost than either rail or legal-weight truck transportation; long transport distances potentially requiring the transit of the Panama Canal outside U.S. territorial waters; transport on intercoastal and coastal waterways of coastal states and on major rivers through and bordering states; extended transportation times; intermodal transfer operations at ports; and land transport from a western port to Yucca Mountain.

DOE also eliminated the truck-cask-on-railcar modal scenarios from future consideration. In this scenario, legal-weight truck casks would be shipped by rail from generator sites to Nevada and then by legal-weight trucks in the State to a Yucca Mountain repository. The purported advantage of this scenario is that DOE could use rail transportation nationally and would not have to construct and operate a branch rail line or upgrade highways, construct an intermodal transfer station, and use heavy-haul trucks in Nevada. DOE determined that while this scenario would be feasible, it would not be practical. The number of shipping casks and railcar shipments would be greater by a factor of 5 than for the mostly rail scenario and the additional cost to the Program would be more than $1 billion. In addition, the truck-casks-on-railcars scenario would lead to the highest estimates of occupational health and public health and safety impacts, most coming from rail-traffic related facilities.

For these reasons, DOE selected the mostly rail and mostly legal-weight truck transportation scenarios as the basis to estimate impacts of transporting spent nuclear fuel to a Yucca Mountain repository. It also evaluated use of barge transportation as a component of the mostly rail scenario for transporting rail casks to nearby railheads from generator sites that could load a rail cask and that are located near navigable waterways but are not served by railroads.

2.3.3.1 Potential Rail Routes Considered but Eliminated from Further Detailed Study

Because rail access is not currently available to the Yucca Mountain site, DOE would have to build a branch rail line from an existing mainline railroad to the repository or transfer rail shipping casks to heavy-haul trucks at an intermodal transfer station to make effective use of rail transportation for shipping spent nuclear fuel and high-level radioactive waste to the repository. Section 2.1.3 describes the 10 implementing rail and intermodal alternatives for Nevada transportation that this EIS evaluates. DOE selected these implementing alternatives based on transportation studies that identified, evaluated, and eliminated other potential Nevada transportation rail and intermodal alternatives (DIRS 104792-YMP 1990, all; DIRS 104795-CRWMS M&O 1995, all; DIRS 101214-CRWMS M&O 1996, all). This section identifies the potential rail and highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated from further detailed study.

In the *Preliminary Rail Access Study* (DIRS 104792-YMP 1990, all), DOE identified 10 potential branch rail line routes to the Yucca Mountain site (Valley, Arden, Jean, Crucero, Ludlow, Mina, Caliente, Carlin, Cherry Creek, and Dike). Figure 2-37 shows these potential rail routes, each named for the area where it would connect to the mainline railroad. Alternatives within each route were developed wherever

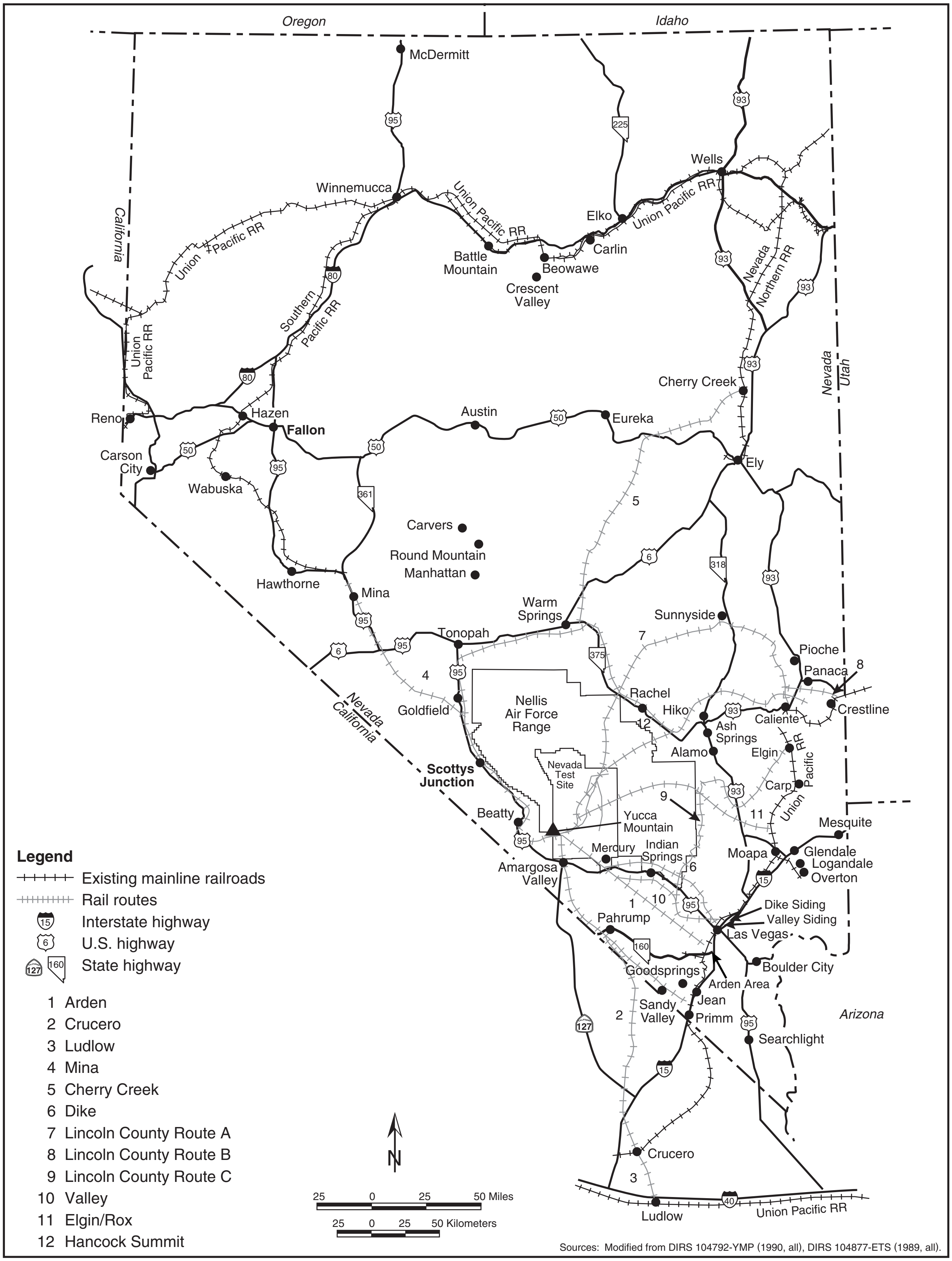


Figure 2-37. Potential rail routes to Yucca Mountain, Nevada, considered but eliminated from further study.

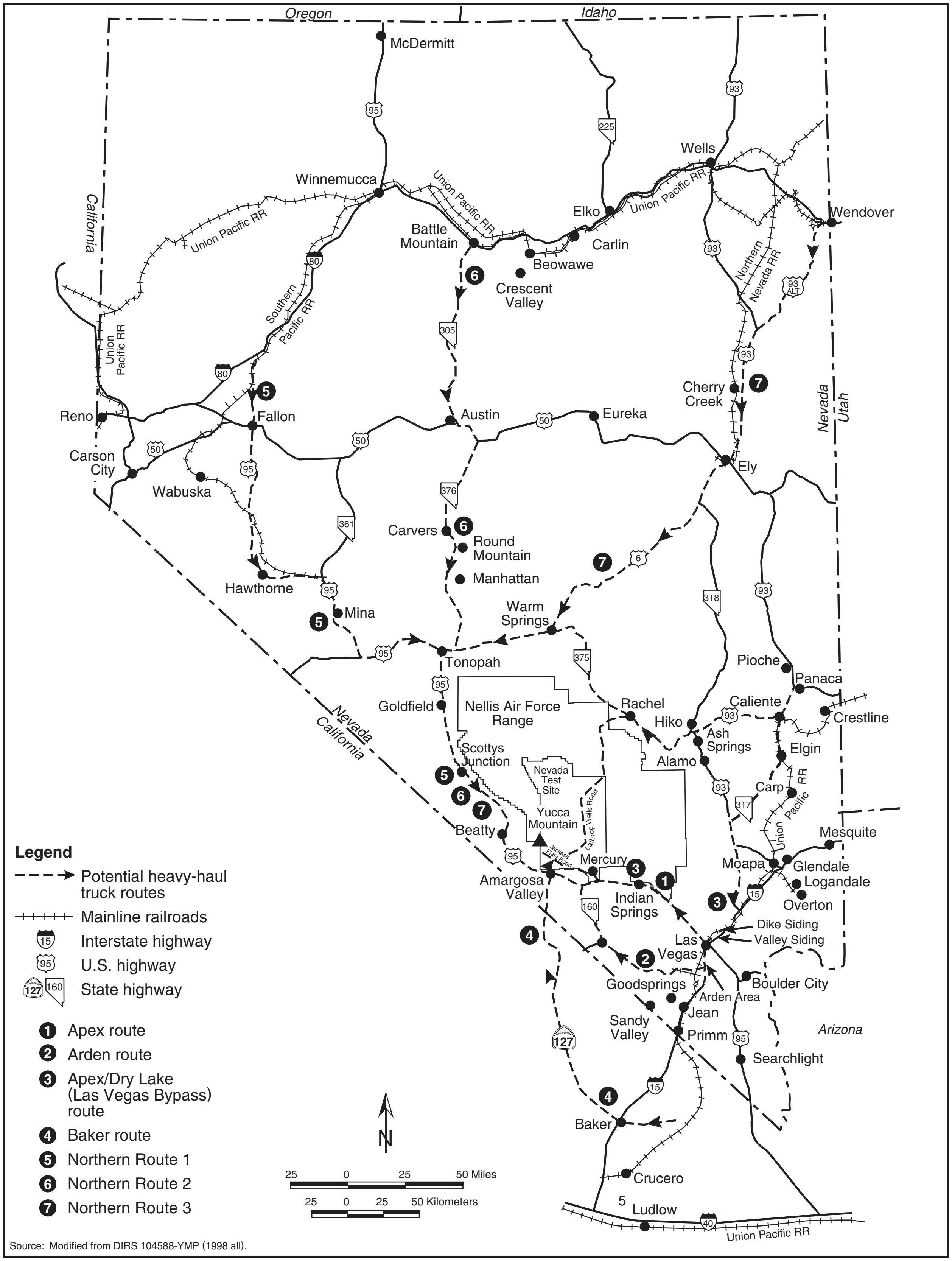
possible. The routes were chosen to maximize the use of Federal lands, provide access to regional rail carriers, avoid obvious land-use conflicts, and meet current railroad engineering practices. After the development of these rail routes, Lincoln County and the City of Caliente identified three additional routes (identified as Lincoln County Routes A, B, and C).

DOE evaluated these 13 potential rail routes in DIRS 104792-YMP (1990, all) and reevaluated them in the *Nevada Potential Repository Preliminary Transportation Strategy, Study 1* (DIRS 104795-CRWMS M&O 1995, all). One new route, Valley Modified, was added in the 1995 study based on updated information from the Bureau of Land Management on the status of two Wilderness Study Areas that represent possible land-use conflicts for the Valley route in the original evaluation. Three additional alignments—Caliente-Chalk Mountain, Elgin/Rox, and Hancock Summit—were evaluated in the Nevada Potential Repository Preliminary Assessment of the Caliente-Chalk Mountain Rail Corridor. The evaluations reviewed each potential rail corridor to identify land-use compatibility issues (the presence or absence of land-use conflicts, and the potential for mitigation of a conflict if one exists) and for access to regional rail carriers. The evaluations also compared other factors of the routes, including favorable topography (gently sloping rather than rugged terrain) and avoidance of lands withdrawn from public use by Federal action. Based on these evaluations, DOE eliminated the Valley, Arden, Crucero, Ludlow, Mina, Cherry Creek, Dike, Elgin/Rox, Hancock Summit, and Lincoln County A, B, and C rail routes from further study.

2.3.3.2 Potential Highway Routes for Heavy-Haul Trucks and Associated Intermodal Transfer Station Locations Considered but Eliminated from Further Detailed Study

DOE identified and evaluated potential highway routes for heavy-haul trucks from existing mainline railroads to the Yucca Mountain site (DIRS 104795-CRWMS M&O 1995, all; DIRS 101214-CRWMS M&O 1996, all; DIRS 154448-CRWMS M&O 1998, all). The Department identified highway routes for heavy-haul trucks and associated intermodal transfer station locations to provide reasonable access to existing mainline railroads, to minimize transport length from an existing mainline rail interchange point, and to maximize the use of roads identified by the Nevada Department of Transportation for the highest allowable axle load limits. In addition to the five implementing intermodal alternatives selected for analysis in this EIS (see Section 2.1.3.3), Figure 2-38 shows highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated from further detailed study. The eliminated alternatives include four routes named for the location of the intermodal transfer station—Apex, Arden, Baker, and Apex/Dry Lake (Las Vegas Bypass)—and three that are representative of routes from the northern Union Pacific mainline railroad (Northern Routes 1, 2, and 3).

DOE considered the development of new roads for dedicated heavy-haul truck shipments. The analysis assumed those routes would be within the corridors identified for potential rail routes, because the selection criteria for heavy-haul routes and rail routes (land-use compatibility issues, access to regional rail carriers, etc.) would be similar (DIRS 101214-CRWMS M&O 1996, p. 6-3). DOE also considered routes for heavy-haul trucks in the potential rail corridors that could use portions of the existing road system for part of the route length. DOE eliminated the development of a new road for heavy-haul trucks from further detailed evaluation, because the construction of a new branch rail line would be only slightly more expensive and because transportation by rail would not require intermodal transfers and would be more efficient (DIRS 101214-CRWMS M&O 1996, p. 6-7).



Source: Modified from DIRS 104588-YMP (1998 all).

Figure 2-38. Potential highway routes for heavy-haul trucks to Yucca Mountain, Nevada, considered but eliminated from further study.

2.4 Summary of Findings and Comparison of the Proposed Action and the No-Action Alternative

This section summarizes and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative (Section 2.2). Detailed descriptions of the impact analyses are contained in the following chapters:

- Chapter 4 describes the short-term environmental impacts associated with construction, operation and monitoring, and closure of the repository and includes the manufacture of waste disposal containers and shipping casks.
- Chapter 5 describes long-term (postclosure) environmental impacts from the disposal of spent nuclear fuel and high-level radioactive waste in the repository.
- Chapter 6 describes the impacts associated with the transportation of spent nuclear fuel, high-level radioactive waste, other materials, and personnel to and from the repository.
- Chapter 7 describes the short-term and long-term impacts associated with the No-Action Alternative.

This EIS defines *short-term impacts* as those that would occur until and during the closure of the repository and *long-term impacts* as those that would occur after repository closure and for as long as 10,000 years.

This section summarizes the findings of the EIS analyses and contains:

- A general comparison of the impacts of the Proposed Action and No-Action Alternative (Section 2.4.1), with an overall summary of the health impacts
- Short-term impacts of repository construction, operation and monitoring, and closure, including impacts for the operating modes analyzed and short-term impacts of the No-Action Alternative (Section 2.4.2)
- Long-term impacts of the Proposed Action and No-Action Alternative (Section 2.4.3)
- Impacts associated with the transportation scenarios and implementing alternatives (Section 2.4.4)

2.4.1 COMPARISON OF PROPOSED ACTION AND NO-ACTION ALTERNATIVE

In general, the EIS analyses showed that the environmental impacts associated with the Proposed Action would be small to moderate, as described in Chapters 4, 5, 6, and 8. For some of the resource areas specifically analyzed in this study, there would be no impacts. Table 2-7 provides an overview approach to comparing the range of impacts for the Proposed Action (divided into repository, combined national and Nevada transportation, and long-term impacts) and the No-Action Alternative (divided into short-term and the two No-Action long-term scenarios). The sections of the EIS where the reader may find more information about the impacts are noted.

Although generally small, environmental impacts would occur under the Proposed Action. DOE would reduce or eliminate many such impacts with mitigation measures (see Chapter 9) or implementation of standard Best Management Practices (see Chapter 9). Under the No-Action Alternative, the short-term impacts would be the same under Scenario 1 or 2. Under Scenario 1, DOE would continue to manage spent nuclear fuel and high-level radioactive waste facilities at 5 DOE sites, and commercial utilities would continue to manage their spent nuclear fuel at 72 sites on a long-term basis and to isolate the

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative[a] (page 1 of 4).

Resource area	Flexible design potential operating modes–range of impacts: Short-term (through closure): Repository	Flexible design potential operating modes–range of impacts: Short-term (through closure): Transportation	Flexible design potential operating modes–range of impacts: Long-term (after closure, to 10,000 years)	No-Action Alternative: Short-term (100 years)	No-Action Alternative: Long-term (100 to 10,000 years): Scenario 1	No-Action Alternative: Long-term (100 to 10,000 years): Scenario 2
Land use and ownership	Small; the flexible design range of disturbed land is from 4.3 km^2[(b)] to about 6.0 km^2 of the 600 km^2 that comprise the analyzed withdrawal area See Section 4.1.1.2	Small to moderate; 0 to about 20 km^2 of land disturbed for new transportation routes; Air Force identified Nellis Air Force Range conflicts for some routes; some routes pass close to or through Wilderness Study Areas; some corridors could directly impact Native Americans and Indian reservations; and one corridor could conflict with the Ivanpah Airport construction and operation See Section 2.4.4 and Chapter 6	Small; potential for limited access into the area; the only surface features remaining would be markers See Section 5.0	Small; storage would continue at existing sites See Section 7.2.1.1	Small; storage would continue at existing sites See Section 7.2.1.1	Large; potential contamination of 0.04 to 0.4 km^2 surrounding each of the 72 commercial and 5 DOE sites See Section 7.2.2.1
Air quality	Small; releases and exposures well below regulatory limits (less than 6 percent of limits) See Section 4.1.2.5	Small; releases and exposures below regulatory limits; pollutants from vehicle traffic and trains would be small in comparison to other national vehicle and train traffic; Clean Air Act General Conformity Requirements might apply in Clark County Nevada See Section 2.4.4, Tables 2-10 and 2-11, and Chapter 6	Very small, 5.3×10^{-10} latent cancer fatalities peak effect See Section 5.5.2	Small; releases and exposures well below regulatory limits See Section 7.2.1.2	Small; releases and exposures well below regulatory limits See Section 7.2.1.2	Small; degraded facilities would preclude large atmospheric releases See Section 7.2.2.2
Hydrology (groundwater and surface water)	Groundwater–small; water demand (230 to 290 acre-feet[c] per year) well below lowest estimate of the groundwater basin's perennial yield (580 acre-feet) See Section 4.1.3.3	Small; withdrawal of up to 710 acre-feet from multiple wells and hydrographic areas over about 4 years See Section 2.4.4 and Chapter 6	Small amounts of contamination of groundwater in Amargosa Valley during the first 10,000 years. Contamination is several hundred thousand times less than the groundwater protection standard in 40 CFR 197 See Section 5.4.2.1	Small; usage would be small in comparison to other site use See Section 7.2.1.3.2	Small; usage would be small in comparison to other site use See Section 7.2.1.3.2	Large; potential for radiological contamination of groundwater around 72 commercial and 5 DOE sites See Section 7.2.2.3.2
	Surface water–small; new land disturbance of 2.8 to 4.5 square kilometers would result in minor changes to runoff and infiltration rates; floodplain assessment concluded impacts would be small See Section 4.1.3.2	Small; minor changes to runoff and infiltration rates; all rail corridors pass through areas of identified 100-year flood zones, additional floodplain assessments would be performed in the future as necessary See Section 2.4.4 and Chapter 6	Small; minor changes to runoff and infiltration rates See Section 5.0	Small; minor changes to runoff and infiltration rates See Section 7.2.1.3.1	Small; minor changes to runoff and infiltration rates See Section 7.2.1.3.1	Large; potential for radiological releases and contamination of drainage basins downstream of 72 commercial and 5 DOE sites (concentrations potentially exceeding current regulatory limits) See Section 7.2.2.3.1

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative[a] (page 2 of 4).

	Flexible design potential operating modes–range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation			Scenario 1	Scenario 2
Biological resources and soils	Small to moderate; loss of about 4.3 km^2 to 6.0 km^2 of desert soil, habitat, and vegetation; adverse impacts to individual threatened desert tortoises (not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; wetlands assessment concluded impacts would be small See Section 4.1.4	Small to moderate; loss of 0 to 20 km^2 of desert soil, habitat, and vegetation for heavy-haul routes and rail corridors; adverse impacts to individual threatened desert tortoises (not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; additional wetlands assessments would be performed in the future as necessary prior to any construction See Section 2.4.4 and Chapter 6	Small; slight increase in temperature of surface soil directly over the repository for 10,000 years resulting in a potential temporary shift in plant and animal communities in this small area (about 8 km^2) See Section 5.0	Small; storage would continue at existing sites See Section 7.2.1.4	Small; storage would continue at existing sites See Section 7.2.1.4	Large; potential adverse impacts at each of the 77 sites from subsurface contamination of 0.04 to 0.4 km^2 See Section 7.2.2.4
Cultural resources	Small to moderate; repository development would disturb up to about 4.5 km^2 of previously undisturbed land; mitigation measures would avoid or minimize damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint See Section 4.1.5.2	Small to moderate; loss of 0 to 20 km^2 of land disturbed for new transportation routes; mitigation measures would avoid or minimize damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint See Section 2.4.4 and Chapter 6	Small; potential for limited access into the area; opposing Native American viewpoint See Section 5.0	Small; storage would continue at existing sites; limited potential of disturbing sites See Section 7.2.1.5	Small; storage would continue at existing sites; limited potential of disturbing sites See Section 7.2.1.5	Small; no construction or operation activities; no impacts See Section 7.2.2
Socioeconomics	Small; estimated peak total employment of 3,400 occurring in 2006 would result in less than a 1 percent increase in composite regional employment; therefore, impacts would be small. Estimated peak direct employment for the repository during construction would be approximately 1,900 in 2006. See Sections 4.1.6.2.1 and 4.1.6.3	Small; employment increases would range from less than 1 percent to 4.9 percent (use of intermodal transfer station in Lincoln County) of employment in affected counties See Section 2.4.4 and Chapter 6	Small; no workers, no impact See Section 5.0	Small; population and employment changes would be small compared to totals in the regions See Section 7.2.1.6	Small; population and employment changes would be small compared to totals in the regions See Section 7.2.1.6	Small; no workers; no impacts See Section 7.2.2
Occupational and public health and safety						
Public						
Radiological[d]						
MEI (probability of an LCF)	1.6×10^{-5} to 3.1×10^{-5} See Section 4.1.7.5.3	1.4×10^{-4} to 1.2×10^{-3} See Sections 6.1.1 and 6.2.3.2	4×10^{-10} to 4×10^{-9} at the boundary of the controlled area (approximately 18 km south of the repository) See Sections 5.4.2.1 and 5.4.2.2	4.3×10^{-6} See Section 7.2.1.7.3	1.3×10^{-6} See Section 7.2.1.7.3	(e)
Population (LCFs)	0.46 to 2.0 See Section 4.1.7.5.2	0.61 to 2.5 See Section 6.1.1	2×10^{-6} to 3×10^{-4} See Sections 5.4.2.1 and 5.4.2.2	0.41 See Section 7.2.1.7.3	3 See Section 7.2.1.7.3	3,300[f] See Section 7.2.2.5.3

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative[a] (page 3 of 4).

Resource area	Flexible design potential operating modes–range of impacts: Short-term (through closure): Repository	Flexible design potential operating modes–range of impacts: Short-term (through closure): Transportation	Flexible design potential operating modes–range of impacts: Long-term (after closure, to 10,000 years)	No-Action Alternative: Short-term (100 years)	No-Action Alternative: Long-term (100 to 10,000 years): Scenario 1	No-Action Alternative: Long-term (100 to 10,000 years): Scenario 2
Occupational and public health and safety (continued)						
Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits See Section 4.1.7	1.6 to 2.8[g] See Sections 6.1.1, 6.1.3, 6.3.2.2.5.6, and 6.3.3.2.1.5	Small; exposures well below regulatory limits or guidelines See Section 5.0	Small; exposures well below regulatory limits or guidelines See Section 7.2.1.7.1	Small; exposures well below regulatory limits or guidelines See Section 7.2.1.7.1	Moderate to large; substantial increases in releases of hazardous substances in the spent nuclear fuel and high-level radioactive waste and exposures to the public See Section 7.2.2
Workers (involved and noninvolved)						
Radiological (LCFs)	4.0 to 6.8 See Section 4.1.7.5.2	3.2 to 11.7 See Section 6.1.1	No workers, no impacts See Section 5.0	16 See Section 7.2.1.7.3	10 See Section 7.2.1.7.3	No workers, no impacts See Section 7.2.2
Nonradiological fatalities (includes commuting traffic fatalities)	2.0 to 3.3 See Section 4.1.7.5.1	12 to 23[h] See Sections 6.1.1, 6.1.3, 6.3.2.2.5.6, and 6.3.3.2.1.5	No workers, no impacts See Section 5.0	9 See Section 7.2.1.7.2 and 7.2.1.14	1,080 See Section 7.2.1.7.2 and 7.2.1.14	No workers, no impacts See Section 7.2.2
Accidents						
Public						
Radiological						
MEI (probability of an LCF)	2.9×10^{-13} to 1.9×10^{-5} See Section 4.1.8.1	0.0015 to 0.015 See Section 6.1.1	Not applicable See Section 5.0	No impacts See Section 7.2.1.8	No impacts See Section 7.2.1.8	Not applicable See Section 7.2.2.7
Population (LCFs)	1.4×10^{-11} to 1.1×10^{-2} See Section 4.1.8.1	0.55 to 5 See Section 6.1.1	Not applicable See Section 5.0	No impacts See Section 7.2.1.8	No impacts See Section 7.2.1.8	3 to 13 See Section 7.2.2.7
Workers	Large; for some unlikely accident scenarios workers would likely be severely injured or killed See Section 4.1.8.1	Large; for some unlikely accident scenarios workers would likely be severely injured or killed See Section 2.4.4 and Chapter 6	No workers, no impacts See Section 5.0	Large; for some unlikely accident scenarios workers would likely be severely injured or killed See Section 7.2.1.8	Large; for some unlikely accident scenarios workers would likely be severely injured or killed See Section 7.2.1.8	Small; no workers; no impacts See Section 7.2.2
Noise/Ground Vibration	Small; impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels – controls and protection used as necessary See Section 4.1.9.2	Small to moderate; transient and not excessive, less noise than 90 dBA[i]; ground vibration infrequent and less than 88 dBV at 25 m See Section 2.4.4 and Chapter 6	Small; no activities, therefore, no noise or ground vibration See Section 5.0	Small; transient and not excessive, less than 90 dBA See Section 7.2.1.9	Small; transient and not excessive, less than 90 dBA See Section 7.2.1.9	Small; no activities, therefore, no noise See Section 7.2.2

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative[a] (page 4 of 4).

	Flexible design potential operating modes – range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation			Scenario 1	Scenario 2
Aesthetics	Small; low adverse impacts to aesthetic or visual resources in the area. There may be increase in lighting impacts due to lighting associated with the ventilation system See Section 4.1.10	Small; possible temporary and transient; conflict with visual resource management goals for Wilson Pass Option of the Jean rail corridor; and discernible impacts from the Caliente Intermodal transfer facility near Kershaw-Ryan State Park. See Section 2.4.4 and Section 6.2	Small; only surface features remaining would be markers See Section 5.0	Small; storage would continue at existing sites; expansion as needed See Section 7.2.1.10	Small; storage would continue at existing sites; expansion as needed See Section 7.2.1.10	Small; aesthetic value decreases as facilities degrade See Section 7.2.2
Utilities, energy, materials, and site services	Small; use of materials would be very small in comparison to amounts used in the region; electric power delivery system to the Yucca Mountain site would have to be enhanced See Section 4.1.11.2	Small; use of materials and energy would be small in comparison to amounts used nationally See Section 2.4.4 and Chapter 6	Small; no use of materials or energy See Section 5.0	Small; materials and energy use would be small compared to total site use See Section 7.2.1.11	Small; materials and energy use would be small compared to total site use See Section 7.2.1.11	Small; no use of materials or energy See Section 7.2.2
Management of site-generated waste and hazardous materials	Small; radioactive and hazardous waste generated would be a few percent of existing offsite capacity; other wastes would be managed onsite See Section 4.1.12.2	Small; waste generated would be a fraction of existing offsite capacity See Section 2.4.4 and Chapter 6	Small; no waste generated or hazardous materials used See Section 5.0	Small; waste generated and materials used would be small compared to total site generation and use See Section 7.2.1.12	Small; waste generated and materials used would be small compared to total site generation and use See Section 7.2.1.12	Small; no waste generated or hazardous materials used See Section 7.2.2
Environmental justice	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint See Section 4.1.13	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint See Section 6.1.2.12	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint See Section 5.0	Small; no disproportionately high and adverse impacts to minority or low-income populations See Section 7.2.1.13	Small; no disproportionately high and adverse impacts to minority or low-income populations See Section 7.2.1.13	Large; potential for disproportionately high and adverse impacts to minority or low-income populations See Section 7.2.2.8

a. Ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

b. km^2 = square kilometers; to convert to acres, multiply by 247.1.

c. To convert acre-feet to cubic meters, multiply by 1233.49.

d. LCF = latent cancer fatality; MEI = maximally exposed individual.

e. With no effective institutional controls, the maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death would be caused by acute direct radiation exposure.

f. Downstream exposed population of approximately 3.9 billion over 10,000 years.

g. Nonradiological fatalities due to exhaust emissions health effects from spent nuclear fuel and high-level radioactive waste transportation, including loadout; exhaust emissions health effects from commuter and materials transportation for repository construction, operation, and closure; and rail line or heavy-haul truck/intermodal transfer station construction, maintenance, and operation.

h. Nonradiological traffic fatalities from spent nuclear fuel and high-level radioactive waste transportation and commuter traffic fatalities. As many as 10 to 17 of these fatalities could be members of the public.

i. dBA = *A-weighted decibels*, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

material from human access with institutional control. Under Scenario 2, with the assumption of no effective institutional control after 100 years, the spent nuclear fuel and high-level radioactive waste storage facilities would begin to deteriorate and radioactive materials could escape to the environment, contaminating the local atmosphere, soils, surface water, and groundwater, thereby representing a considerable human health risk. As described in Chapter 7, if DOE increased the assumed institutional control period to be consistent with the repository preclosure period (100 to 324 years), the short-term impacts would range up to three times those reported for the No-Action Alternative, depending on the environmental resource area evaluated.

The range of potential health impacts for the Proposed Action, depending on the operating mode, and for the No-Action Alternative are shown in Table 2-8. The transportation-related impacts presented in Table 2-8 represent those associated with the preferred transportation mode (mostly rail). The range of health impacts to workers and the public for repository construction, operation and monitoring, and closure including the full range of possible transportation scenarios and modes would be 24 to 49 fatalities (see Table 2-7), whereas the health impacts for repository construction, operation and monitoring, and closure using the preferred mode of transportation (mostly rail) would be 24 to 38 fatalities (see Table 2-8).

2.4.2 SHORT-TERM IMPACTS OF THE PROPOSED ACTION REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE AND NO-ACTION ALTERNATIVE

DOE analyzed short-term impacts (project start to the end of closure) for the Proposed Action and No-Action Alternative in various resource areas. The information presented in Table 2-7 shows that the short-term environmental impacts for the Proposed Action and the No-Action Alternative would generally be small and do not differentiate dramatically between the two alternatives. The analyses also included cost estimates for the two alternatives. Estimated short-term (to the end of closure) costs (in 2001 dollars) for the Proposed Action would range from $43 to $58 billion, and those for the No-Action Alternative would be as much as $61 billion for the same period (see Sections 2.1.5 and 2.2.3).

To construct the analytical basis for evaluation of repository impacts, DOE used widely accepted analytical tools to estimate potential environmental impacts, coupled with the best available information, and cautious but reasonable assumptions where uncertainties exist. This included applying conservative assumptions to the set of reasonable operating scenarios identified in the Science and Engineering Report (DIRS 153849-DOE 2001, p. 2-24) to ensure that the EIS did not underestimate potential environmental impacts and to accommodate the greatest range of potential future actions.

DOE has established parameters for the range of potential repository operating modes and has identified these parameters and their ranges in Table 2-2. These operating modes provide the basis for evaluation of the environmental impacts described in Chapter 4. Ensuring that the range of potential impacts evaluated fully encompasses the impacts that could occur under any reasonable repository mode of operation requires a basic understanding of how the particular impacts relate to the various parameters, particularly those parameters that could be varied to achieve lower-temperature operation.

As shown in the Draft EIS and the Supplement to the Draft EIS, the short-term impacts (preclosure) would increase with the size of the repository and surface facilities. The smallest repository and surface facilities are associated with the higher-temperature repository operating mode and therefore would result in the lowest short-term environmental impacts. As detailed in Section 2.1.1.2.2, the lower-temperature repository operating mode would be achieved by varying several of the design parameters independently or in combination, for differing effects. Design parameters include waste package loading, repository ventilation duration, and waste package spacing. In the analyses, DOE maximized each of these parameters in turn, and assumed reasonably conservative values for the other dependent parameters to

Table 2-8. Health and safety impact comparison of Proposed Action to No-Action Alternative.[a]

Proposed Action impacts (0 to 10,000 years)		No-Action impacts (0 to 10,000 years)	
Impacts for the preclosure period (up to 341 years)		Impacts from 0 to 100 years	
Radiological		Radiological	
Loadout and transportation of SNF and HLW	4 LCFs	Loadout and transportation of SNF and HLW	0 LCFs
Construction and operations at repository	4 - 8 LCFs	Construction and operations	16 LCFs
Subtotal	8 - 12 LCFs	Subtotal	16 LCFs
Nonradiological		Nonradiological	
Transportation via mostly rail		Transportation (materials and commuting)	7 fatalities
SNF and HLW to Yucca Mountain	3 - 4 fatalities	Construction and operations	2 fatalities
Nevada railroad construction and maintenance	1 - 2 fatalities	Subtotal	9 fatalities
Repository construction, operation and monitoring, and closure	10 - 17 fatalities		
Construction and operations at repository	2 - 3		
Subtotal	16 - 26 fatalities		
Total (preclosure period)	***24 - 38 fatalities or LCFs***	***Total (0 to 100 years)***	***25 fatalities or LCFs***
		Impacts from 100 to 10,000 years	
Impacts from closure to 10,000 years		With institutional control	No institutional control
Radiological	~0 LCF	~13 LCFs	~3,300 LCFs
Transportation	0 fatalities	~760 fatalities	0 fatalities
Construction and operations	0 fatalities	~320 fatalities	0 fatalities
Total (0 to 10,000 years)	***24 - 38 fatalities or LCFs***	***~1,120 fatalities or LCFs***	***~3,325 fatalities or LCFs***

a. Abbreviations: SNF = spent nuclear fuel; HLW = high-level radioactive waste; LCF = latent cancer fatality.

evaluate the full range of potential environmental impacts. As an example, DOE considered a repository with the largest waste package spacing (6.4 meters), with and without the use of surface aging. The result was the largest repository and surface facilities and therefore the highest potential impacts for some environmental resource areas (for example, land disturbance, nonradiological air quality, and water use). Conversely, when DOE assumed the long postemplacement ventilation period (300 years), with and without the surface aging facility, the result was a repository that would be open for a longer period with higher potential for impacts to workers and release of naturally occurring radon from the open repository to the offsite public. DOE evaluated the reasonable combinations of these variable design parameters to establish the range of impacts reported in Chapter 4 and summarized in Table 2-7.

For the No-Action Alternative, short-term actions would be limited to termination of activities and reclamation at the Yucca Mountain site, as well as continued management and storage of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites across the United States. Short-term actions at the repository would include dismantling and removal of surface structures, rehabilitating land disturbed during characterization activities, salvage of usable equipment and materials, sealing of boreholes, and grating of portals. Because the activities (for example, earth moving, facility removal, and site reclamation) would be essentially the reverse of facility construction and reclamation of the site is expected to require 1 year, DOE estimated the resultant impacts as essentially equal to 1 year of repository construction activities (see Chapter 7, Section 7.1, for more details).

For the 77 generator sites, impacts resulting from continued management and storage of spent nuclear fuel and high-level radioactive waste were estimated based on actual operational experience at DOE and commercial storage facilities. In addition, the short-term impacts for the No-Action Scenarios 1 and 2 would be essentially the same because both scenarios assume institutional controls remain in place for the first 100 years. The information in Table 2-7 generally reflects environmental impacts at the generator sites, because the short-term impacts of No-Action at the repository would be much smaller than the collective impacts at the 77 generator sites.

2.4.3 LONG-TERM IMPACTS OF THE PROPOSED ACTION AND THE NO-ACTION ALTERNATIVE

In addition to the short-term impacts described above, DOE assessed the impacts from radiological and nonradiological hazardous materials released over a much longer period (100 years to as long as 10,000 years) after the closure of the repository (for the Proposed Action, DOE also estimated the peak *dose* for the post-10,000 year period). These projections are based essentially on the best available scientific techniques. DOE focused the assessment of long-term impacts on human health, biological resources, surface-water and groundwater resources, and other resource areas for which the analysis determined the information was particularly important.

The EIS also examined possible biological impacts from the long-term production of heat by the radioactive materials disposed of in Yucca Mountain. The analysis determined that there would be small or no long-term impacts to land use, *noise*, socioeconomic resources, cultural resources, surface-water resources, aesthetics, utilities, or site services from the Proposed Action and limited impacts from the No-Action Alternative, depending on the scenario. The analysis led to the following conclusions:

- From 0.04 to 0.4 square kilometer (10 to 100 acres) of land could be contaminated to the extent it would not be usable for long periods near each of the 77 sites for No-Action Scenario 2. There could be accompanying impacts on biological resources, socioeconomic conditions, cultural resources, and aesthetic resources for long periods. Such impacts for the Proposed Action and No-Action Scenario 1 would be very small.

- For No-Action Scenario 2, there could be low levels of contamination in the surface watershed and high concentrations of contaminants in the groundwater downstream of the 77 sites for long periods. There would be no such impacts for No-Action Scenario 1. For the Proposed Action, there could be very low levels of contamination in the groundwater in the *Amargosa Desert* for a long period.

- Projected radiological impacts to the public for the first 10,000 years for the Proposed Action would be low (about 2×10^{-6} to 3×10^{-4} *latent cancer fatality* per year) compared to No-Action Scenario 2 (3,300 latent cancer fatalities over 10,000 years).

- Radionuclides would be released for a long period of time under the Proposed Action and peak doses would occur about 480,000 years after closure of the repository. The peak mean annual effective *dose equivalent* would be 120 to 150 *millirem*.

- Projected long-term (10,000 years) fatalities associated with No-Action Scenario 1 would be about 1,000, primarily to the workforce at the storage sites.

- Risks associated with sabotage and materials diversion in relation to the fissionable material stored at the 77 sites would be much greater than they would be if the fissionable material were in a monitored deep geologic repository.

The projected cost associated with No-Action Scenario 1 would range from $520 million to $570 million a year (2001 dollars) (see Section 2.2.3) for 9,900 years. Projected long-term costs for the Proposed Action would be very low while there would be none for No-Action Scenario 2 due to the lack of institutional control.

2.4.4 IMPACTS OF TRANSPORTATION SCENARIOS

Table 2-7 summarizes the full range of transportation impacts for the construction, operation and maintenance, and closure of the proposed repository, including the mostly rail and mostly legal-weight truck scenarios and the impacts of constructing and using the Nevada implementing alternatives. This range bounds the transportation-related impacts that could occur. Table 2-8 summarizes health and safety impacts for construction, operation and maintenance, and closure of the repository using the preferred transportation mode of mostly rail nationally and in the State of Nevada.

The following sections address health impacts from the movement of spent nuclear fuel and high-level radioactive waste across the Nation (Section 2.4.4.1) and impacts that could occur in the State of Nevada for the legal-weight truck, rail, and heavy-haul truck implementing alternatives (Section 2.4.4.2). The impacts discussed in both sections are included in Tables 2-7 and 2-8, and are described here to show the comparative difference between the 10 transportation implementing alternatives.

2.4.4.1 National Transportation

This section summarizes and compares national transportation-related environmental impacts for the movement of spent nuclear fuel and high-level radioactive waste from the 77 sites to the Yucca Mountain site. Table 2-9 compares the environmental impacts for the two national transportation scenarios, mostly rail and mostly legal-weight truck (see Section 2.1.3.2). Because DOE does not know the actual mix it would use for these potential national transportation modes, the analyses used these two scenarios to bound the impacts from reasonably expected transportation activities that would move spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. In addition to national impacts, Table 2-9 includes estimates of the environmental impacts associated with transportation in Nevada.

Table 2-9. National transportation impacts for the transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail and mostly legal-weight truck scenarios.[a,b]

Group	Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Worker	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	48[c]	48[c]
	Individual latent cancer fatality probability	0.02	0.02
	Collective dose (person-rem)	29,000	7,900 - 8,800
	Latent cancer fatality incidence	11.7	3.2 - 3.5[d]
	Industrial safety (fatalities)	0.9	0.29
Public	*Incident-free health impacts, radiological*		
	Average exposed individual (rem)	0.0005	0.0001
	Maximally exposed individual (rem)	2.4[e]	0.29
	Individual latent cancer fatality probability	0.0012	0.00014
	Collective dose (person-rem)	5,000	1,200 - 1,600
	Latent cancer fatality incidence	2.5	0.61 - 0.81
	Incident-free vehicle emissions impacts (fatalities)	0.95	0.55 - 0.77
	Radiological impacts from maximum reasonably foreseeable accident scenario		
	Frequency (per year)	2.3 in 10,000,000	2.8 in 10,000,000
	Maximally exposed individual (rem)	3	29
	Individual latent cancer fatality probability	0.0015	0.015
	Collective dose (person-rem)	1,100	9,900
	Latent cancer fatality incidence	0.55	5
	Accident dose risk (person-rem)	0.46	0.89
	Accident risk (latent cancer fatalities)	0.00023	0.00045
Public and transportation workers	*Fatalities from vehicular accidents*	4.9	2.3 - 3.1

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operation, including impacts of loading.
c. Based on 2-rem-per-year dose limit.
d. Range for the 10 rail and heavy-haul truck implementing alternatives in Nevada.
e. Based on 100-millirem-per-year dose limit.

As discussed in more detail in Chapter 6, shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be a small fraction of the overall railroad and highway shipping activity in the United States. Thus, the incremental impacts from shipments to Yucca Mountain for the resource areas would be small in comparison to background impacts from all shipping activities, with the exception of potential radiological impacts.

The following conclusions can be drawn from the analysis results summarized in Table 2-9:

- Radiological impacts from maximum foreseeable accident scenarios during the transportation of spent nuclear fuel and high-level radioactive waste would be lower for the mostly legal-weight truck scenario. The likelihood that such an accident would occur is extremely small for all scenarios.

- Impacts from the transportation of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site would be low for either national shipping mode.

- Radiological impacts to the public and to workers for national transportation activities would be lower for the mostly rail scenario.

2.4.4.2 Nevada Transportation

For shipments coming into the State of Nevada by rail, there is no branch rail line to connect the national rail routes with the Yucca Mountain site (see Section 2.1.3.3). As a consequence, DOE evaluated the impacts in Nevada of moving spent nuclear fuel and high-level radioactive waste to the site using 10 implementing alternatives. These included five potential corridors for a new branch rail line (see Section 2.1.3.3.2) and five potential combinations of intermodal transfer stations and highway routes for heavy-haul trucks (see Section 2.1.3.3.3).

Tables 2-10 and 2-11 compare the impacts from transportation activities in potential Nevada rail corridors and heavy-haul truck corridors, respectively, and includes the mostly legal-weight truck scenario impacts that would occur in Nevada. In addition, they list the distance of each route. The results include the potential corridor variations in the routes chosen, construction required, and operations. The impacts summarized in Tables 2-10 and 2-11 are based on the impact analyses in Chapter 6, Sections 6.3.1, 6.3.2, and 6.3.3, which delineate the corridor variations. Additional attributes such as cost, institutional acceptability of the route, construction and schedule risk, and operational compatibility could affect a decision on the choice of a transportation mode or route in Nevada.

The following conclusions can be drawn from the information in Tables 2-10 and 2-11:

- Environmental impacts for each of the 10 implementing alternatives would be small.
- With the exception of *collective dose*, the environmental impacts for shipment by legal-weight truck in Nevada would be smaller than those from the 10 implementing alternatives associated with incoming shipments by mostly rail scenario. However, even for shipment by legal-weight truck in Nevada, the projected collective dose impacts would be small (approximately 0.9 latent cancer fatality to both the public and transportation workers) over 24 years.
- With the exception of land use, differences in environmental impacts for the 10 implementing alternatives related to incoming shipments by mostly rail scenario would be small, so environmental impacts do not appear to be a major factor in the selection of transportation mode, route, or corridor in Nevada for incoming rail shipments.
- As much as about 20 square kilometers (4,900 acres) of land would be disturbed for new transportation routes. Three of the rail corridors would encroach on the western and southern boundaries of the Nellis Air Force Range. Of these three, one short segment of the Valley Modified Corridor would not have a variation that could avoid the encroachment. The Caliente-Chalk Mountain Corridor and the Caliente/Chalk Mountain heavy-haul truck route would travel directly through the range. The U.S. Air Force has stated that any route through the Range would have national security implications. Several rail corridors pass through or near Wilderness Study Areas or the proposed Ivanpah Valley Airport. Rail or heavy-haul truck routes could affect the Timbisha Shoshone trust lands, Las Vegas Paiute Reservation, or Moapa Reservation. Some routes could overlap predicted Las Vegas-area growth. Heavy-haul trucks would slow traffic flow.
- Impacts to cultural resources for any of the potential implementing alternative routes or corridors cannot be fully assessed until more detailed archaeological and ethnographic studies are conducted, but they are likely to be similar to one another. Impacts to Native American values could occur from the use of any of the routes including the use by legal-weight trucks of highways in Nevada that would pass through the Moapa and Las Vegas Paiute Indian Reservations.

2.5 Collection of Information and Analyses

DOE conducted a broad range of studies to obtain or evaluate the information needed for the assessment of Yucca Mountain as a monitored geologic repository for spent nuclear fuel and high-level radioactive waste. The Department used the information from these studies in the analyses described in this EIS. Because some of these studies are ongoing, some of the information is incomplete.

Table 2-10. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 1 of 2).

Impact	Mostly rail with branch rail					Mostly legal-weight truck
	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	
Corridor length (kilometers)	512 - 553	514 - 544	344 - 382	181 - 204	159 - 163	230 - 270
Land use and ownership						
Disturbed land (square kilometers)[a]	18 - 20	19 - 20	13 - 14	9.2 - 10	5 - 5.2	0
Private land (square kilometers)	0.9 - 2.5	7.3 - 15	0.8 - 1.1	0.1 - 3.5	0 - 0.18	0
Nellis Air Force Range land (square kilometers)	0 - 11	0 - 11	22	0	3.6 - 7.5	0
Tribal	0 - 1.6	0 - 1.6	0	0	0	0
Air quality						
PM_{10} and carbon monoxide (construction and operations)	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - branch rail line not a significant source of pollution	Clark County is in nonattainment of air quality standards for PM_{10} - branch rail line construction could be a significant source of pollution[b]	Not a significant source of pollution
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Surface water resources along route	5	6	3	0	0	NA[d]
Flood zones	9	11	At least 3	7	2	NA
Groundwater						
Water use (acre-feet)[c]	710	660	480	410	320	0
Water use (number of wells)	64	67	43	23	20	0
Biological resources and soils	Low	Low	Low	Low	Low	Very low
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological or historical resources. Route passes close to the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Moderate	Low	Moderate	Moderate	Moderate	Low
Utilities and resources						
Diesel (million liters)[e]	45	41	36	30	14	Very low
Gasoline (thousand liters)	940	840	680	570	280	
Steel (thousand metric tons)[f]	78	75	52	29	23	0
Concrete (thousand metric tons)[g]	460	420	310	170	130	0

Table 2-10. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 2 of 2).

Impact	Mostly rail with branch rail: Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Mostly legal-weight truck
Aesthetics	Very low	Very low	Very low	Potential small area of conflict	Very low	None
Socioeconomics						
New jobs (percent of workforce in affected counties	840 (< 1% - 3.2%)	780 (< 1%)	650 (<1% - 2.3%)	530 (< 1%)	250 (< 1%)	Very low
Peak real disposable income (million dollars)	24	21	19	15	7	Very low
Peak incremental Gross Regional Product (million dollars)	40	36	31	26	13	Very low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Very low
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	220	200	180	150	110	NA
Lost workday cases	110	100	90	80	60	NA
Fatalities	0.43	0.41	0.38	0.3	0.25	NA
Collective dose (person-rem [LCFs])						
Workers	850 [0.34]	980 [0.39]	740 [0.3]	760 [0.3]	710 [0.28]	1,900 [0.75]
Public	19 [0.009]	38 [0.019]	50 [0.025]	130 [0.06]	23 [0.012]	340 [0.17]
Fatalities from vehicle emissions	0.25	0.25	0.2	0.23	0.13	0.086
Accident impacts, nonradiological traffic						
Construction and operations workforce	1.9	1.8	1.5	1.2	0.9	NA
SNF[h] and HLW[i] shipping	0.07	0.09	0.05	0.06	0.05	0.49
Accident impacts, radiological						
Radiological accident risk						
Person-rem	0.002	0.003	0.002	0.007	0.002	0.053
Latent cancer fatalities	0.0000009	0.0000013	0.0000009	0.0000036	0.000001	0.000026
Maximum reasonably foreseeable accident						
Maximally exposed individual (rem)	29	29	29	29	29	0.3
Individual latent cancer fatality probability	0.014	0.014	0.014	0.014	0.014	0.0015
Collective dose (person-rem)	9,900	9,900	9,900	9,900	9,900	1,100
Latent cancer fatalities	4.9	4.9	4.9	4.9	4.9	0.55

a. Convert square kilometers to acres, multiply by 247.1.
b. To convert acre-feet to gallons, multiply by 325,850.1.
c. To convert liters to gallons, multiply by 0.26418.
d. To convert metric tons to tons, multiply by 1.1023.
e. To convert cubic feet to cubic meters, multiply by 0.028317.
f. NA = not applicable.
g. SNF = spent nuclear fuel.
h. HLW = high-level radioactive waste.
i. Conformity analysis may be required (see Chapter 3, Sections 3.1.2.1 and 3.2.2.1.2).

Table 2-11. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 1 of 3).

	Mostly rail with heavy-haul truck					
Impact	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Corridor length (kilometers)	530	280	380	190	180	230 - 270
Land use and ownership						
Disturbed land (square kilometers)[a]	3.4	1.3	2.1	0.63	0.63	0
Private land (square kilometers)	0	0	0	0	0	0
Nellis Air Force Range land (square kilometers)	0	0	0	0	0	0
Air quality						
PM_{10} and carbon monoxide (construction and operations)	Areas in attainment of air quality standards - not a significant source of pollution	Areas in attainment of air quality standards - not a significant source of pollution	Clark County is in nonattainment of air quality standards - heavy-haul route construction could be a significant source of pollution[b]	Except in Clark County, areas in attainment of air quality standards - not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - not a significant source of pollution	Not a significant source of pollution
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Groundwater						
Water use (acre-feet)[c]	100	60	44	8	8	0
Water use (number of wells)	16	5	7	Truck water	Truck water	0
Biological resources and soils	Low	Low	Low	Low	Low	Very low
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources; route near Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; route passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; IMT[d] and route near the Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Low	Low	Low	Low	Low	Low
Utilities and resources						
Diesel (million liters)[e]	13	4.7	5.5	1.7	1.6	Very low
Steel (metric tons)[f]	49	14	21	2.3	2.3	0
Concrete (thousand metric tons)[g]	1.8	0.5	0.8	0.1	0.1	0
Aesthetics	Some potential near Caliente	Some potential near Caliente	Some potential near Caliente	Very low	Very low	None

Table 2-11. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 2 of 3).

Impact	Mostly rail with heavy-haul truck: Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Socioeconomics						
New jobs (percent of workforce in affected counties)	860 (< 1% - 3.3%)	750 (< 1% - 4.9%)	590 - 1,980 (< 1% - 3.3%)	630 - 3,050 (< 1%)	490 - 1,880 (< 1%)	Very low
Peak real disposable personal income (million dollars)	27	22	19 - 65	21 - 97	16 - 62	Very low
Peak incremental Gross Regional Product (million dollars)	45	40	33 - 104	36 - 153	29 - 100	Very low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Very low
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	310	270	260	150	150	NA[h]
Lost workday cases	160	140	140	80	80	NA
Fatalities	0.72	0.68	0.63	0.37	0.37	NA
Collective dose (person-rem [LCFs])						
Workers	1,600 [0.65]	1,200 [0.50]	1,400 [0.56]	1,200 [0.48]	1,100 [0.46]	1,900 [0.75]
Public	76 [0.038]	61 [0.030]	220 [0.11]	300 [0.15]	160 [0.08]	340 [0.17]
Fatalities from vehicle emissions	0.47	0.32	0.46	0.42	0.29	0.086
Accident impacts, nonradiological traffic						
Construction and operations workforce	3.5	2.4	3.0	1.7	1.7	NA
SNF[i] and HLW[j] shipping	0.6	0.33	0.43	0.25	0.23	0.49
Accident impacts, radiological						
Radiological accident risk						
Person-rem	0.01	0.002	0.056	0.12	0.056	0.053
Latent cancer fatalities	0.0000051	0.000001	0.000028	0.00006	0.000028	0.000026

Table 2-11. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 3 of 3).

Impact	Mostly rail with heavy-haul truck					Mostly legal-weight truck
	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	
Maximum reasonably foreseeable accident						
Maximally exposed individual (rem)	29	29	29	29	29	3
Individual latent cancer fatality probability	0.014	0.014	0.014	0.014	0.014	0.0015
Collective dose (person-rem)	9,900	9,900	9,900	9,900	9,900	1,100
Latent cancer fatalities	4.9	4.9	4.9	4.9	4.9	0.55

a. To convert square kilometers to acres, multiply by 247.1.
b. To convert acre-feet to gallons, multiply by 325,850.1.
c. IMT = intermodal transfer.
d. To convert liters to gallons, multiply by 0.26418.
e. To convert metric tons to tons, multiply by 1.1023.
f. To convert cubic feet to cubic meters, multiply by 0.028317.
g. NA = not applicable.
h. SNF = spent nuclear fuel.
i. HLW = high-level radioactive waste.
j. Conformity analysis may be required (see Chapter 3, Sections 3.1.2.1 and 3.2.2.1.2).

The complexity and variability of the natural system at Yucca Mountain, the long periods evaluated, and factors such as the use of incomplete information or the unavailability of information have resulted in a certain degree of uncertainty associated with the analyses and findings in this EIS. DOE believes that it is important that the EIS identify the use of incomplete and unavailable information and uncertainty to enable an understanding of its findings. It is also important to understand that research can produce results or conclusions that might disagree with other research. The interpretation of results and conclusions has resulted in the development of views that differ from those that DOE presents in this EIS. DOE has received input from a number of organizations interested in the Proposed Action or No-Action Alternative or from potential recipients of impacts from those actions. These organizations include among others the State of Nevada, local governments, and Native American tribes. Their input includes documents that present research or information that in some cases disagrees with the views that DOE presents in this EIS. The Department reviewed these documents and evaluated their findings for inclusion as part of the EIS analyses. If the information represents a substantive view, DOE has made every effort to incorporate that view in the EIS and to identify its source.

2.5.1 INCOMPLETE OR UNAVAILABLE INFORMATION

Some of the analyses in this EIS had to use incomplete information. To ensure an understanding of the status of its information, DOE has identified the use of incomplete information or the unavailability of information in the EIS in accordance with the Council on Environmental Quality regulations pertaining to incomplete and unavailable information (40 CFR 1502.22). Such cases describe the basis for the analyses, including assumptions, the use of preliminary information, or conclusions from draft or incomplete studies. DOE continues to study issues relevant to understanding what could happen in the future at Yucca Mountain and the potential impacts associated with its use as a repository. As a result, this Final EIS includes information that was not available for the Draft EIS. DOE believes that sufficient information is currently available to assess the range of impacts that could result from either the Proposed Action or the No-Action Alternative.

2.5.2 UNCERTAINTY

The results and conclusions of analyses often have some associated uncertainty. The uncertainty could be the result of the assumptions used, the complexity and variability of the process being analyzed, the use of incomplete information, or the unavailability of information. To enable an understanding of the status of its findings, this EIS contains descriptions of the uncertainties, if any, associated with the results and conclusions presented. Chapter 5, Section 5.2.4 provides further description of uncertainties associated with estimating long-term impacts.

2.5.3 OPPOSING VIEWS

In this EIS, opposing views are defined as differing views or opinions currently held by organizations or individuals outside DOE. These views are considered to be opposing if they include or rely on data or methods that DOE is not currently using in its own impact analysis. In addition, these views are reasonably based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in the EIS.

DOE has attempted to identify and address the range of opposing views in this EIS. The Department identified potential opposing views by reviewing public comments received during the EIS comment period, as well as, published or other information in the public domain. Sources of information included reports from universities, other Federal agencies, the State of Nevada, counties, municipalities, other local governments, and Native American tribes. DOE reviewed the potential opposing views to determine if they:

- Address issues analyzed in the EIS
- Differ from the DOE position
- Are based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in the EIS
- Have significant basic differences in the data or methods used in the analysis or to the impacts described in the EIS

DOE has included potential opposing views that met the above criteria in the EIS where it discusses the particular subject. For example, opposing views on the groundwater system are discussed in the sections on groundwater.

2.5.4 PERCEIVED RISK AND STIGMA

PERCEIVED RISK AND STIGMA

DOE uses the term risk perception to mean how an individual perceives the amount of risk from a certain activity. Studies show that perceived risk varies with certain factors, such as whether the exposure to the activity is voluntary, the individual's degree of control over the activity, the severity of the exposure, and the timing of the consequences of the exposure.

DOE uses stigma to mean an undesirable attribute that blemishes or taints an area or locale.

During the scoping process for the Draft EIS, commenters requested DOE to evaluate the potential impacts that could arise from risk perception and stigma associated with the construction and operation of a repository at Yucca Mountain and from the transportation of spent nuclear fuel and high-level radioactive waste. Commenters stated that negative perceptions of the repository and associated transportation would result in substantial adverse socioeconomic impacts, particularly in Nevada.

In considering the request to evaluate the impacts of risk perception and stigma, DOE recognized that nuclear facilities can be perceived to be either positive or negative, depending on the underlying value systems of the individual forming the perception. Thus, perception-based impacts would not necessarily depend on the actual physical impacts or risk of repository operations, including transportation. A further complication is that people do not consistently act in accordance with negative perceptions, and thus the connection between public perception of risk and future behavior would be uncertain or speculative at best. For these reasons, DOE concluded that including analyses of perception-based and stigma-related impacts in the Draft EIS would not provide meaningful information.

Comments on the Draft EIS and Supplement to the Draft EIS once again raised the issue of risk perception and stigma. In response, DOE examined relevant studies and literature on perceived risk and stigmatization of communities to determine whether the state of the science in predicting future behavior based on perceptions had advanced sufficiently since scoping to allow DOE to quantify the impact of public risk perception on economic development or property values in affected communities. Of particular interest were those scientific and social studies carried out in the past few years that directly relate to either Yucca Mountain or to DOE actions, such as the transportation of foreign research reactor fuel (see Appendix N). DOE also reexamined the conclusions of previous literature reviews, such as that conducted in 1995 by the Nuclear Waste Technical Review Board.

After completing its review, DOE concluded that, although public perception regarding the proposed geologic repository and transportation of spent nuclear fuel and high-level radioactive waste could be measured, there is no valid method to translate these perceptions into quantifiable economic impacts. Researchers in the social sciences have not found a way to reliably forecast linkages between perceptions or attitudes reported in surveys and actual future behavior. Based on the current limitations in forecasting future behavior attributable to risk perception or stigma, there is a consensus among social scientists that a quantitative assessment of economic impacts from risk perception and stigma is impossible at this time. At best, only a *qualitative* assessment is possible about what broad outcomes seem most likely.

Qualitatively, in the absence of a large accident or a continuing series of smaller accidents, there is little reason to expect that negative perceptions about repository operations are likely to engender adverse effects (see Appendix N). Likewise, absent accidents, there is no reason to expect that risk perceptions would impact property values in areas beyond the transportation corridors. Some studies (DIRS 156055-UER 2001, all; DIRS 156003-Gawande and Jenkins-Smith 2001, all) report that, at least temporarily, a small relative decline in residential property values might result from the designation of transportation corridors in urban areas, even in the absence of accidents. Other transportation experiences (for example, transportation of *transuranic waste* to the Waste Isolation Pilot Plant) suggest that impacts on property values might be negligible or nonexistent.

Based on the general research to date on perceptions and future behavior, and research related specifically to a Yucca Mountain repository, other nuclear facilities, and transportation of spent nuclear fuel and high-level radioactive waste, DOE has concluded that:

- While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable methods whereby such impacts could be quantified with any degree of certainty.
- Much of the uncertainty is irreducible.
- Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

While stigmatization of southern Nevada can be envisioned under some scenarios, it is not inevitable or numerically predictable. Any such stigmatization would likely be an aftereffect of unpredictable future events, such as serious accidents, which may not occur. Consequently, DOE did not attempt to quantify any potential for impacts from risk perceptions or stigma in this EIS.

The studies and literature reviewed are referenced in a report included in Appendix N, *Are Fear and Stigmatization Likely, and How Do They Matter? Lessons from Research on the Likelihood of Adverse Socioeconomic Impacts from Public Perceptions of the Yucca Mountain Repository* by Dr. Robert O'Connor.

2.6 Preferred Alternative

DOE's preferred alternative is to proceed with the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The analyses in this EIS did not identify any potential environmental impacts that would be the basis for not proceeding with the Proposed Action. Further, DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada.

DOE recognizes that implementation of the Proposed Action would require the completion of a number of actions. As part of this process, the Secretary of Energy is to:

- Undertake (and complete) site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Determine whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the NWPA requires that a comprehensive statement of the basis for the recommendation, including this Final EIS, accompany the recommendation. DOE has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS and other information described below, in making a determination on whether to recommend the site to the President. The NWPA also requires DOE to hold hearings to provide the public in the vicinity of Yucca Mountain with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, the Secretary made a determination to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary would submit the recommendation to the President to approve the site for development of a repository.

If, after a recommendation by the Secretary, the President considered the site qualified for application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may object to the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submitted such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature did submit such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

In determining whether to recommend the Yucca Mountain site to the President, the Secretary would consider not only the potential environmental impacts identified in this EIS, but other information designated in Section 114 of the NWPA. These include, for example, a description of the proposed repository, preliminary engineering specifications for the facility, a description of the proposed waste form, an explanation of the relationship between the proposed waste form or packaging and geologic medium of the site, a discussion of the site characterization data that relates to the safety of the site, preliminary comments of the Nuclear Regulatory Commission concerning the sufficiency of information for inclusion in any Departmental license application, and the views and comments of the Governor and Legislature of any State or the governing body of any affected Native American tribe.

As part of the Proposed Action, which DOE has identified as its preferred alternative, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation nationally and in Nevada, as well as impacts in Nevada of alternative intermodal (rail-to-truck) transfer stations associated routes for heavy-haul trucks and alternative corridors for a branch rail line. The analysis did not identify any potential environmental impacts that would be a basis for not transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site.

DOE believes that the EIS provides the environmental impact information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside

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Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

DOE has identified mostly rail as it preferred mode of transportation, both nationally and in Nevada. The environmental impacts for mostly rail are expected to be less overall than the impacts for mostly truck. For the mostly rail scenario, 9,600 rail and 1,100 truck shipments are expected for shipping 70,000 MTHM and, for the mostly truck scenario, 53,000 truck and 300 rail shipments are expected. The reduced number of shipments to move 70,000 MTHM and corresponding expected reduction in environmental impacts are the basis for preferring the mostly rail scenario.

NONPREFERRED ALTERNATIVES

DOE has identified the Caliente-Chalk Mountain rail corridor and heavy-haul truck route as "nonpreferred alternatives." The U.S. Air Force has stated that it knows of no route across the Nellis Air Force Range (now known as the Nevada Test and Training Range) that would avoid militarily sensitive areas and not affect the heavy volume of testing and training that occurs daily. Therefore, the Air Force believes that such a route would be inconsistent with the national security uses of the Range.

At this time, DOE has not identified a preference for a specific rail corridor in Nevada. If the Yucca Mountain site was approved, DOE would identify such a preference in consultation with affected stakeholders, particularly the State of Nevada. In that case, DOE would announce its preferred corridor in Nevada in a *Federal Register* notice. Following the *Federal Register* notice, DOE would publish its decision to select a corridor in a Record of Decision no sooner than 30 days after the announcement of a preference. However, follow-on implementing decisions, such as selection of a specific rail alignment in a corridor, would require additional field surveys, state and local government consultations, Native American tribal consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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3

Affected Environment

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3. AFFECTED ENVIRONMENT

To analyze potential environmental impacts that could result from the implementation of the Proposed Action, the U.S. Department of Energy (DOE) has compiled extensive information about the environments that could be affected. The Department used this information to establish the *baseline* against which it measured potential impacts (see Chapter 4). Chapter 3 describes (1) environmental conditions that will exist at and in the region of the proposed repository site at Yucca Mountain after the conclusion of site characterization activities (Section 3.1); (2) environmental conditions along the proposed transportation corridors in Nevada that DOE could use to ship spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site (Section 3.2); and (3) environmental conditions at the 72 commercial and 5 DOE sites in the United States that manage spent nuclear fuel and high-level radioactive waste (Section 3.3).

DOE obtained baseline environmental information from many sources. These sources included reports and studies sponsored by DOE, other Federal agencies (for example, the U.S. Geological Survey), and the State of Nevada and affected units of local government. Affected units of local government include Nye County, which is the county in which the repository site is located, by DOE decision as allowed under the Nuclear Waste Policy Act, as amended (this EIS refers to the amended Act as the NWPA), counties contiguous to Nye County (that is, Clark, Lincoln, White Pine, Eureka, Lander, Churchill, Mineral, and Esmeralda Counties in Nevada and Inyo County in California). In addition, DOE has sought input from Elko County, Nevada, which could be affected by transportation activities associated with the Proposed Action.

DOE received reports from the State of Nevada and affected units of local government during the EIS scoping process, informally from local government personnel, and formally during ongoing interactions between DOE and State and local governments. The subjects of these reports include socioeconomics, cultural resources, hydrology, transportation planning and emergency response, and resource supply. DOE evaluated these reports and, where appropriate, they are discussed in individual resource area sections of the EIS.

3.1 Affected Environment at the Yucca Mountain Repository Site at the Conclusion of Site Characterization Activities

To define the existing environment at and in the region of the proposed repository, DOE has compiled environmental baseline information for 13 subject areas. This environment includes the manmade structures and physical disturbances from DOE-sponsored site selection studies (1977 to 1988) and site characterization studies (1989 to 2001) to determine the suitability of the site for a repository. This chapter and supporting documents, called *environmental baseline files,* contain baseline information for:

- *Land use and ownership:* Land-use practices and land ownership information in the Yucca Mountain region (Section 3.1.1)
- *Air quality and climate:* The quality of the air in the Yucca Mountain region and the area's climatic conditions (temperature, precipitation, etc.) (Section 3.1.2)
- *Geology:* The geologic characteristics of the Yucca Mountain region both at and below the ground surface, the frequency and severity of seismic activity, volcanism, and mineral and energy resources (Section 3.1.3)
- *Hydrology:* Surface-water and groundwater features in the Yucca Mountain region and the quality of the water (Section 3.1.4)

- *Biological resources and soils:* Plants and animals that live in the Yucca Mountain region, the occurrence of special status species and *wetlands*, and the kinds and quality of soils in the region (Section 3.1.5)

- *Cultural resources:* Historic and archaeological resources in the Yucca Mountain region, the importance those resources hold, and for whom (Section 3.1.6)

- *Socioeconomic environment:* The labor market, population, housing, some public services, real *disposable income*, *gross regional product*, government spending, and DOE payment equal to taxes in the Yucca Mountain region (Section 3.1.7)

- *Occupational and public health and safety:* The levels of radiation that occur naturally in the Yucca Mountain air, soil, animals, and water; radiation dose estimates for Yucca Mountain workers from *background radiation*; radiation exposure, dispersion, and accumulation in air and water for the Nevada Test Site area from past nuclear testing and current operations; and public radiation dose estimates from background radiation (Section 3.1.8)

- *Noise and Vibration:* Noise and vibration sources and levels of noise and vibration that commonly occur in the Yucca Mountain region during the day and at night, and the applicability of Nevada standards for noise in the region (Section 3.1.9)

- *Aesthetics:* The visual resources of the Yucca Mountain region in terms of land formations, vegetation, and color, and the occurrence of unique natural views in the region (Section 3.1.10)

- *Utilities, energy, and materials:* The amount of water available for the Yucca Mountain region, water-use practices, water sources, the demand for water at different times of the year, the amounts of power supplied to the region, the means by which power is supplied, and the availability of natural gas and propane (Section 3.1.11)

- *Waste and hazardous materials:* Ongoing solid and hazardous waste and wastewater management practices at Yucca Mountain, the kinds of waste generated by current activities at the site, the means by which DOE disposes of its waste, and DOE recycling practices (Section 3.1.12)

- *Environmental justice:* The locations of *low-income* and *minority populations* in the Yucca Mountain region and the income levels among low-income populations (Section 3.1.13)

DOE evaluated the existing environments in regions of influence for each of the 13 subject areas. Table 3-1 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict impacts, if any, related to the proposed repository. Human health risks from exposure to airborne *contaminant* emissions were assessed for an area within approximately 80 kilometers (50 miles), and economic effects, such as job and income growth, were evaluated in a three-county socioeconomic region.

In the past, the vicinity around Yucca Mountain has been the subject of a number of studies in support of mineral and energy resource exploration, nuclear weapons testing, and other DOE activities at the Nevada Test Site. From 1977 to 1988, the Yucca Mountain Project performed studies to assist in the site selection process for a repository. These studies, which involved the development of roads, drill holes, trenches, and seismic stations, along with non-Yucca Mountain activities, disturbed about 2.5 square kilometers (620 acres) of land in the vicinity of Yucca Mountain (DIRS 104854-YMP 1998, p. 1). Yucca Mountain site characterization activities began in 1989 and continued through 2001. These activities include surface excavations, excavations of exploration shafts, subsurface excavations and borings, and testing to evaluate the suitability of Yucca Mountain as the site for a repository. As of 2001, these activities have

Table 3-1. Regions of influence for the proposed Yucca Mountain Repository.

Subject area	Region of influence
Land use and ownership	Land around site of proposed repository that DOE would disturb and over which DOE would need to obtain control; analyzed land withdrawal area is 600 square kilometers[a] (Section 3.1.1).
Air and climate	An approximate 80-kilometer[b] radius around Yucca Mountain, and at boundaries of controlled lands surrounding Yucca Mountain (Section 3.1.2).
Geology	The regional geologic setting and the specific geology of Yucca Mountain (Section 3.1.3).
Hydrology	*Surface water:* construction areas that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of the repository that would be affected by eroded soil or potential spills of contaminants.
	Groundwater: aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction, and aquifers downstream of the repository that repository use or long-term releases from the repository could affect (Section 3.1.4).
Biological resources and soils	Area that contains all potential surface disturbances resulting from the Proposed Action (described in Chapter 2) plus some additional area to evaluate local animal populations; roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (Section 3.1.5).
Cultural resources	Land areas that repository activities would disturb (described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur (Section 3.1.6).
Socioeconomic environment	Three Nevada counties (Clark, Lincoln, and Nye) in which repository activities could most influence local economies and populations (Section 3.1.7).
Occupational and public health and safety	An approximate 80-kilometer radius around Yucca Mountain and at the approximate boundary of analyzed land withdrawal area (Section 3.1.8).
Noise and vibration	Existing residences in the Yucca Mountain region and at the approximate edge of the analyzed land withdrawal area (Section 3.1.9).
Aesthetics	Approximate boundary of analyzed land withdrawal area (Section 3.1.10).
Utilities, energy, and materials	Public and private resources on which DOE would draw to support the Proposed Action (for example, private utilities, cement suppliers) (Section 3.1.11).
Waste and hazardous materials	On- and offsite areas, including landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of site-generated repository waste (Section 3.1.12).
Environmental justice	Varies with the different subject areas. The environmental justice regions of influence will correspond to those of the specific subject areas, as defined in this table (Section 3.1.13).

a. 600 square kilometers = about 150,000 acres or 230 square miles.
b. 80 kilometers = about 50 miles.

disturbed about an additional 1.5 square kilometers (370 acres) in the vicinity of Yucca Mountain (DIRS 104508-CRWMS M&O 1999, Table 6-2). Reclamation activities have started and will continue to occur as sites are released from further study.

The existing environment at Yucca Mountain includes the Exploratory Studies Facility, which includes the tunnel (drift), the North and South Portal pads and supporting structures, an excavated rock storage area, a topsoil storage area, borrow pits, boreholes, trenches, roads, and supporting facilities and disturbances for site characterization activities. Table 3-2 lists facilities, structures, equipment, and disturbances at Yucca Mountain and at the central support site in Area 25 of the Nevada Test Site. Area 25 was used in the early 1960s by the Atomic Energy Commission (a DOE predecessor agency) and the National Aeronautics and Space Administration as part of a program to develop nuclear reactors for use in the Nation's space program. The former Nuclear Rocket Development Station administrative areas complex in Area 25 has become the Yucca Mountain Site Characterization Central Support Site. As noted in the table, several of the Area 25 functions have been relocated to the North Portal site since the publication of the Draft EIS.

Table 3-2. Existing facilities, structures, and disturbances at Yucca Mountain.[a]

Yucca Mountain	Area 25 Central Support Site
Exploratory Studies Facility (North Portal pad and supporting structures)	Field Operations Center (moved)[b]
Exploratory Studies Facility (South Portal pad)	Hydrologic research facility
Cross drift[c]	Sample management facility and warehouse
Concrete batch plant and precast yard	Radiological studies facility (moved)[b]
Fill borrow pits (3) and screening plants	Meteorology/air quality studies facility (moved)[b]
Subdock equipment storage facility	Project accumulation area for hazardous waste
Equipment/supplies laydown yard	Gas station
Hydrocarbon management facility	Maintenance facility
Boxcar equipment and supplies yard	U.S. Geological Survey technical warehouse (moved)[b]
Water wells J-12 and J-13	Tunnel rescue facility
Excavated rock storage pile	Sewage lagoon operated by the Nevada Test Site
Topsoil storage pile	
Explosives storage magazines (2)	
Water booster pump and distribution system	
Boreholes (about 300)	
Trenches and test pits (about 200)	
Busted Butte geologic test drift	
Fran Ridge heated-block test facility	
Water infiltration test sites	
Meteorological monitoring towers	
Air quality monitoring sites	
Radiological monitoring sites	
Ecological study plots	
Reclamation study plots	
Septic system	
Roads	

a. Source: Modified from DIRS 148111-CRWMS M&O (1998, all) and DIRS 155933-Jacobs (2001, all).
b. These functions have been relocated to the North Portal site since the Draft EIS was published.
c. Drift is a mining term for a horizontal tunnel.

DOE has made revisions to this section since the Draft EIS to present newly acquired information that contributes to an improved (or updated) understanding of the potentially *affected environment* at Yucca Mountain and its region, and to include information and suggestions for improvement provided through public comments on the Draft EIS and the Supplement to the Draft EIS. The following items summarize key changes to the EIS that deal with the affected environment at the Yucca Mountain site:

- Corrections and updates were made to *land use* figures and text, including changes to the breakout of Nevada land by controlling authority to be consistent with recent land transactions. Clarification was provided on the statutory requirements associated with the proposed land withdrawal, on the rationale for the size of the withdrawal, and on the breakout of the agencies with administrative authority over the land.

- *Air quality and climate* text was modified to better describe the attainment status of areas outside the region of influence and to discuss Federal agency responsibilities under the *conformity* provisions of the Clean Air Act. A new section was added to describe paleoclimatology studies that have been performed as part of the Yucca Mountain Project.

- Minor text changes, including facts and figures, were made to both the *geology* and *hydrology* discussions in response to comments and to ensure consistency with updated information in the new primary source document, the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, all). Several geology and hydrology figures were improved with better graphics or additional information, and several figures were added.

- A new *geology* discussion was added on the formation and characteristics of fractures found in the rock at Yucca Mountain. An update was added to describe the status of ongoing efforts to monitor crustal strain rates in the area.

- Text was added or modified in *hydrology* discussions to better describe the direction of groundwater and the lack of water observed in the subsurface during tunneling at Yucca Mountain, and to provide information on the Devils Hole National Monument and on Nevada Test Site groundwater modeling efforts. Updates were added to describe the status of ongoing efforts to collect additional hydrologic information, including those resulting from the cooperative agreement between Nye County and DOE to investigate the groundwater flow system downgradient of Yucca Mountain. Updates were also added to discuss efforts to validate and verify chlorine-36 study results, and to study postulated evidence of past upwelling of the water table.

- The *biological resources* discussion of plant species in the area of Yucca Mountain was expanded to include identification of exotic species. Text was modified to describe more accurately the opposing viewpoint expressed by the State of Nevada with respect to the biological studies performed as part of the Yucca Mountain Project.

- *Socioeconomics* text and indicator numbers were revised to incorporate updated information from State of Nevada and local agency population estimates. Text was added to explain the basis for using these numbers rather than numbers anchored in 2000 Census data that became available since the publication of the Draft EIS. Socioeconomic indicator data (Gross Regional Product, government spending, and real disposable income) were added and discussions in several key areas were expanded to include estimates of socioeconomic indicators to 2035.

- The region of influence population *distribution* presented in the *occupational and public health and safety* discussion was changed to the new population estimates and is now described for both 2000 and 2035. The discussion of natural radiation sources was revised for clarity and accuracy. Tables and text were revised to better describe background/baseline radiation exposures and their effects at Yucca Mountain, in Nevada, and at other sites in the United States. A new section was added to discuss regional effects from past weapons testing at the Nevada Test Site.

- New text and a new table were added to the *noise* discussions to introduce the concept of vibration as an element of environmental assessment. The existing discussion of noise was augmented with a description of noise threshold levels that present hearing hazards as opposed to annoyance.

- Clarifying text was added to the *aesthetics* section's discussion of the Bureau of Land Management Visual Resource Management system, and particularly for the system's scenic quality component. Text was added describing nighttime darkness as an element of aesthetics for the Yucca Mountain region.

- Updated information was included in discussions of *utilities, energy, and site services*, as well as for *waste and hazardous materials***.**

- *The environmental justice* discussion was expanded to better described the evaluation methodology and updated to incorporate 2000 Census data on minority communities. (The 1990 Census data still represents the most current available data for low-income communities.)

3.1.1 LAND USE AND OWNERSHIP

The *region of influence* for land use and ownership includes land at the site of the proposed repository that DOE would not disturb and the lands that surround the site of the proposed repository over which DOE would have to obtain permanent control to operate the repository. The Department has compiled land-use and ownership information for this region. Most of the land in the region is managed by agencies of the Federal Government. Sections 3.1.1.1 and 3.1.1.2 discuss land use and ownership for the region of influence and for a larger area around Yucca Mountain. Section 3.1.1.3 describes the *analyzed land withdrawal area* for the repository. Section 3.1.1.4 discusses Native American views about the ownership of the land around Yucca Mountain. The Environmental Baseline File for Land Use (DIRS 104993-CRWMS M&O 1999, all) is the basis of the information in this section unless otherwise noted.

3.1.1.1 Regional Land Use and Ownership

The Federal Government manages more than 85 percent of the land in Nevada (about 240,000 square kilometers or 93,000 square miles). Most of this land is under the control of the Bureau of Land Management (which is part of the U.S. Department of the Interior), the U.S. Department of Defense, and DOE. The remainder of the Federally managed land is primarily under the jurisdiction of the Forest Service, which is part of the U.S. Department of Agriculture, with smaller areas under the control of the National Park Service and the Bureau of Reclamation, both of which are parts of the Department of the Interior. About 42,000 square kilometers (16,000 square miles) are under State, local, or private ownership, and about 5,000 square kilometers (2,000 square miles) are Native American lands. Table 3-3 summarizes Nevada land holdings and the controlling authority. Figure 3-1 shows ownership and use of lands around the site of the proposed repository.

The Nevada Test Site, which is a DOE facility, covers about 3,700 square kilometers (1,400 square miles). The Atomic Energy Commission, a DOE predecessor agency, established the Nevada Test Site in the 1950s to test nuclear devices. More information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all). The U.S. Air Force operates the Nellis Air Force Range [its name recently changed to the Nevada Test and Training Range (DIRS 157220-BLM 2001, all)], which covers about 12,000 square kilometers (4,500 square miles) and is one of the largest and most active military training ranges in the United States. More information on current and future uses of the Nellis Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all). The Military Lands Withdrawal Act of 1999, approved by the passage of Public Law 106-65 on October 5, 1999, went into effect on

Table 3-3. Nevada land areas and controlling authorities (square kilometers).[a,b]

Authority	Area	Percentage[c]
State, local, county, or private	42,000	15
Bureau of Land Management	194,000	68
Department of Defense	13,000	5
Department of Energy	3,700	1
Other Federal authorities	26,000	9
Native American tribes	5,000	2

a. Source: DIRS 104993-CRWMS M&O (1999, p. 1); DIRS 103472-USAF (1999, pp. 2-8 to 2-10); and DIRS 154121-DOI (2000, Volume I, p. 19)
b. To convert square kilometers to square miles, multiply by 0.3861.
c. Percentages calculated from area numbers prior to rounding and are shown to the nearest 1 percent.

November 6, 2001 and extended the affected land withdrawal until November 6, 2021. Actions taken under the Act at the Nellis Range also affected lands managed by the Bureau of Land Management and the Department of Energy (DIRS 103472-USAF 1999, pp. 2-8 to 2-10). Approximately 140 and 520 square kilometers (55 and 200 square miles) of land were transferred from the Department of Defense (that is, the Nellis Range) to the Bureau of Land Management (for public use) and DOE, respectively. Approximately 160 square kilometers (60 square miles) of land formerly withdrawn for use by DOE was transferred to the Department of Defense. The Nevada land areas and controlling authorities summarized in Table 3-3 incorporate these changes.

The region has special-use areas, which generally are excluded from development that would require terrain alterations unless such alterations would benefit wildlife or public recreation. The Fish and Wildlife Service of the U.S. Department of the Interior manages the Desert National Wildlife Range and the Ash Meadows National Wildlife Refuge, which are about 50 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively (Figure 3-1). These areas provide *habitat* for a number of resident and migratory animal species in relatively undisturbed natural ecosystems. The National Park Service manages Death Valley National Park, which is in California and Nevada approximately 35 kilometers (22 miles) southwest of Yucca Mountain. The small enclave of Devils Hole Protective Withdrawal in Nevada adjacent to the east-central boundary of Ash Meadows is also administered by the National Park Service (Figure 3-1). The Timber Mountain *Caldera* National Natural Landmark is located primarily on the Nellis Air Force Range and the Nevada Test Site. The Landmark is just north of the proposed repository withdrawal area. The Timber Mountain Caldera is also designated as an Area of Critical Environmental Concern (DIRS 157220-BLM 2001, p. 2-9).

CALDERA

A volcanic crater that has a diameter many times that of the vent. It is formed by collapse of the central part of a volcano or by explosions of extraordinary violence. The erupted materials are commonly spread over great distances beyond the caldera. Volcanic debris that erupted from the Timber Mountain and other calderas north of Yucca Mountain formed the southwestern Nevada volcanic field of which the volcanic rocks at Yucca Mountain are a part.

There is virtually no State-owned land immediately adjacent to the repository site. There are scattered tracts of private land in and near communities such as Beatty and Indian Springs in Nevada. There are also larger private tracts in the Las Vegas Valley, around Pahrump, and in the south-central portion of the large area that makes up Amargosa Valley. The closest year-round housing is at what was once referred to as Lathrop Wells, about 22 kilometers (14 miles) south of the site. This location is now part of the unincorporated Town of Amargosa Valley. There is farming—primarily grasses and legumes—for hay and dairy operations about 30 kilometers (19 miles) south of the proposed repository (Figure 3-1).

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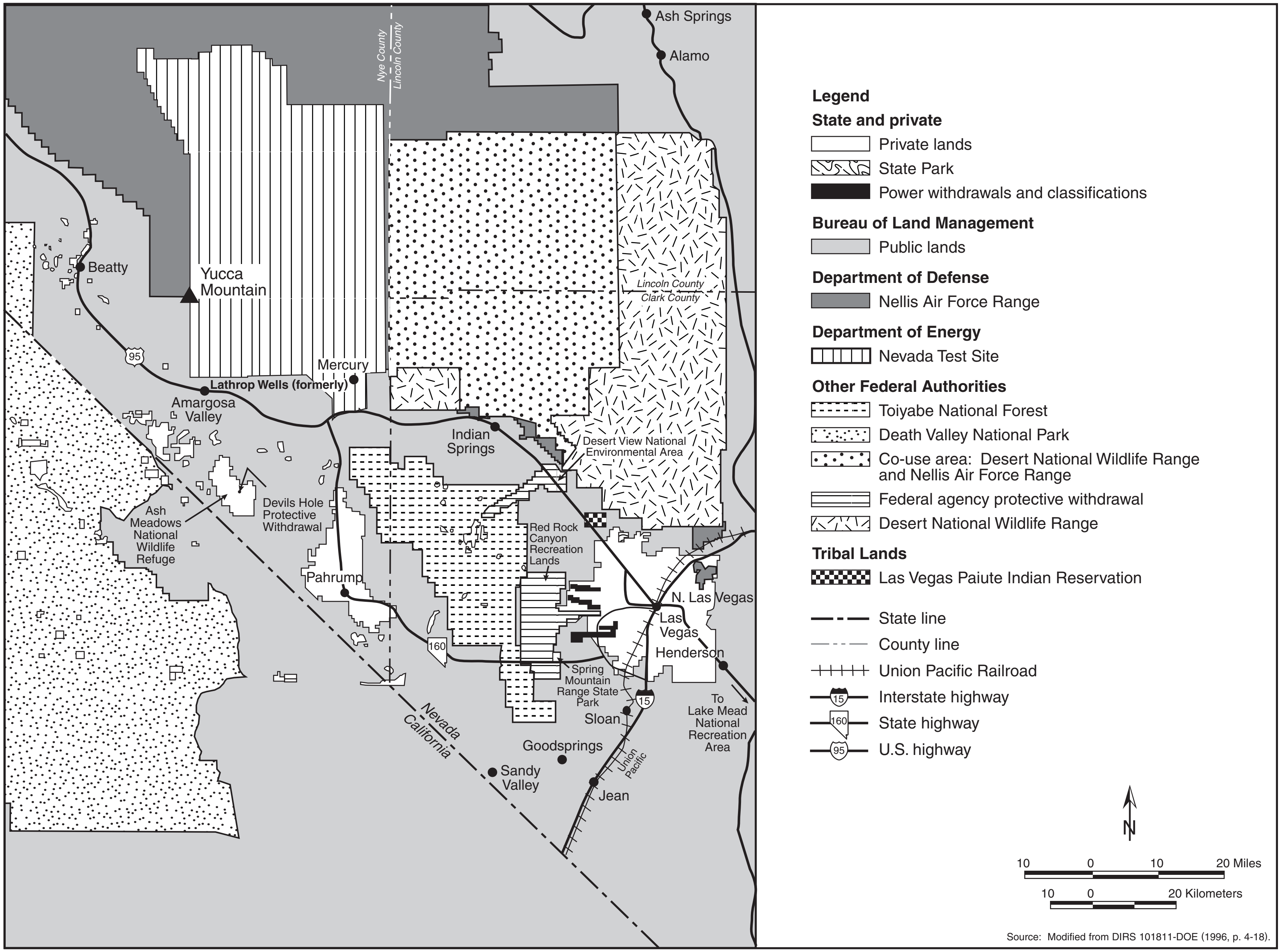

Figure 3-1. Land use and ownership in the Yucca Mountain region.

3.1.1.2 Current Land Use and Ownership at Yucca Mountain

DOE has established land-use agreements to support its site characterization activities at Yucca Mountain. The Yucca Mountain Site Characterization Zone (Figure 3-2) includes DOE, Bureau of Land Management, and Air Force lands.

The Bureau of Land Management granted DOE a right-of-way reservation (N-47748) for Yucca Mountain site characterization activities (DIRS 102218-BLM 1988, all). This reservation comprises 210 square kilometers (52,000 acres). The land in this reservation is open to public use, with the exception of about 20 square kilometers (5,000 acres) near the site of the proposed repository that were withdrawn in 1990 from the mining and mineral leasing laws to protect the physical integrity of the repository block (P.L. Order 6802, "Withdrawal of Public Land to Maintain the Physical Integrity of the Subsurface Environment, Yucca Mountain Project"). The lands in this reservation not withdrawn from the mining and mineral leasing laws contain a number of unpatented mining claims (lode and placer). In addition, there is one patented mining claim surrounded by the reservation. Patented Mining Claim No. 27-83-0002 covers 0.8 square kilometer (200 acres) to mine volcanic cinders used as a raw material in the manufacture of cinderblocks.

The Bureau of Land Management manages surface resources on the Nellis Air Force Range. In 1994, the Bureau granted DOE a right-of-way reservation (N-48602) to use about 75 square kilometers (19,000 acres) of Nellis land for Yucca Mountain site characterization activities (DIRS 102219-BLM 1994, all). This land, which is closed to public access and use, has been studied extensively. Many of the exploratory facilities are on Nellis land.

The Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office have a management agreement that allows the use of about 230 square kilometers (58,000 acres) of Nevada Test Site land for site characterization activities. The Land Facility Use Management Policy under the Memorandum of Agreement with the Nevada Test Site gives the Yucca Mountain Project technical responsibility independent of, but in coordination with, environmental activities at the Nevada Test Site. The Yucca Mountain Project is in compliance with the agreement, which requires it to meet the same environmental requirements that apply to the Nevada Test Site.

3.1.1.3 Potential Repository Land Withdrawal

Nuclear Regulatory Commission initial licensing conditions for a monitored geologic repository (10 CFR Part 60) have been modified under 10 CFR Part 63 to include risk-informed, performance-based environmental regulations. These conditions include a requirement that the lands for which DOE is seeking a repository license be either acquired and under the jurisdiction and control of DOE or be permanently withdrawn and reserved for its use. As noted, portions of the lands being used for site characterization that would be required for the repository are controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office. Because all of these lands are not under permanent DOE control, a land withdrawal would be required.

The procedure for land withdrawal is the method by which the Federal Government places exclusive control over land it owns with a particular agency for a particular purpose. Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Congress can authorize and direct a permanent withdrawal of lands such as those required for the proposed repository at Yucca Mountain. The extent and conditions of the withdrawal would be determined by Congress. The extent of a land withdrawal area is important to the analysis and understanding of the impacts of the Proposed Action. For example, the magnitude of impacts to a member of the public from an accident at an operating repository would be determined in part by the proximity of the land withdrawal boundary to

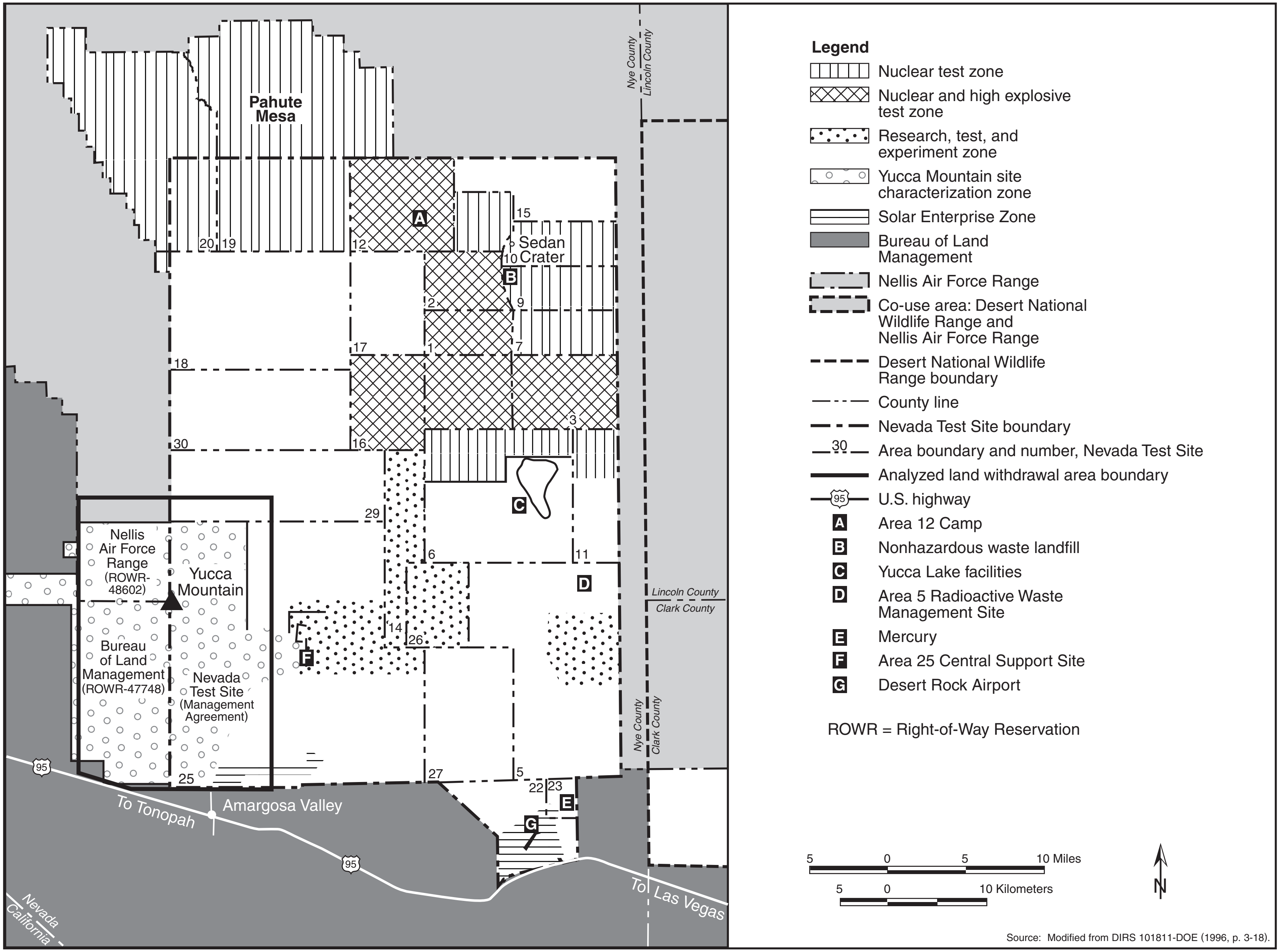

Figure 3-2. Land use and ownership in the analyzed land withdrawal area and vicinity.

the repository operations areas. As a consequence, DOE used a conservative land withdrawal area to extend control toward the closest populated area, the Town of Amargosa Valley, Nevada, thus preventing future encroachment as the basis for analysis in this EIS. The identification of either a restricted or *controlled area* boundary would be defined as part of the licensing process, if there was a determination to proceed with the Yucca Mountain Repository.

Figure 3-2 shows the land withdrawal area analyzed in this EIS that encompasses the current right-of-way reservations for site characterization. This area includes about 600 square kilometers (150,000 acres) of land. The land in this area is currently under the control of the Air Force, DOE, and the Bureau of Land Management (Table 3-4). Approximately 180 square kilometers (45,000 acres) of Bureau of Land Management land in the southwestern portion of the withdrawal area overlaps the taxing district for the unincorporated Town of Amargosa Valley, Nevada. This taxing district, described under Section 18.04.010 of the Nye County Code and Nye County Ordinance 136, encompasses approximately 1,300 square kilometers (320,000 acres). The 180 square kilometers of overlap is Federal land that the Bureau of Land Management administers as public land under a multiple-use classification that the Federal Government has not conveyed to a municipality.

Table 3-4. Current land administration and public accessibility to the analyzed land withdrawal area.[a,b]

Agency	Area (square kilometers)[c]	Current accessibility
DOE (Nevada Test Site)	320	No public access
U.S. Air Force (Nellis Air Force Range)	96	No public access
Bureau of Land Management (public land)	180	Public access
Private land (one patented mining claim)	1	No public access

a. Source: DIRS 153650-YMP (1998, all); DIRS 101521-BLM (1992, all).
b. A description of the area by township, range, and section is available from DOE, Las Vegas, Nevada.
c. To convert square kilometers to square miles, multiply by 0.3861; to convert to acres, multiply by 247.1.

Most of the land controlled by the Bureau of Land Management in the analyzed land withdrawal area is associated with the current right-of-way reservation (N-47748) for Yucca Mountain site characterization activities. This land is open to public use, with the exception of about 20 square kilometers (5,000 acres) near the site of the proposed repository that are withdrawn from the mining and mineral leasing laws and an existing patented mining claim (No. 27-83-0002). The lands open to public use also contain a number of unpatented mining claims (lode and placer). Off-road vehicle use is permitted in these lands. There is a designated utility corridor in the southern portion of these lands.

More detailed descriptions of the land under the control of the Bureau of Land Management in the region of Yucca Mountain are available in the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

3.1.1.4 Native American Treaty Issue

One Native American ethnic group with cultural and historic ties to the Yucca Mountain region is the Western Shoshone. A special concern of the Western Shoshone people is the Ruby Valley Treaty of 1863. The Western Shoshone people maintain that the treaty gives them rights to 97,000 square kilometers (24 million acres) in Nevada, including the Yucca Mountain region (DIRS 102216-Western Shoshone v. United States 1997, all). The legal dispute over the land began in 1946 when the Indian Claims Commission Act gave tribes the right to sue the Federal Government for unkept treaty promises. If a tribe were to win a claim against the Government, the Act specifies that the tribe could receive only a monetary award and not land or other remunerations.

The Western Shoshone people filed a claim in the early 1950s alleging that the Government had taken their land. The Indian Claims Commission found that Western Shoshone title to the Nevada lands had gradually extinguished and set a monetary award as payment for the land. In 1976, the Commission entered its final award to the Western Shoshone people, who dispute the Commission findings and have not accepted the monetary award for the lands in question. They maintain that a settlement has not been reached (the U.S. Treasury is holding these monies in an interest-bearing account) and that Yucca Mountain is on Western Shoshone land. A 1985 U.S. Supreme Court decision (DIRS 148197-United States v. Dann 1985, all) ruled that even though the money has not been distributed, the United States has met its obligations with the Commission's final award and, as a consequence, the aboriginal title to the land had been extinguished.

3.1.2 AIR QUALITY AND CLIMATE

The region of influence for air quality is an area within a radius of about 80 kilometers (50 miles) around the site of the proposed repository and at the boundaries of controlled lands around Yucca Mountain. This region encompasses portions of Esmeralda, Clark, Lincoln, and Nye Counties in Nevada and a portion of Inyo County, California. To determine the air quality and climate for the Yucca Mountain region, DOE site characterization activities have included the monitoring of air quality and meteorological conditions. The Department has monitored the air for gaseous *criteria pollutants* (*carbon monoxide*, nitrogen dioxide, *ozone*, and *sulfur dioxide*) and for *particulate matter*. This section describes the existing air quality and climate at the proposed repository site and in the surrounding region. Sections 3.1.2.1 and 3.1.2.2 describe the air quality and climate, respectively. Unless otherwise noted, the *Environmental Baseline File for Meteorology and Air Quality* (DIRS 102877-CRWMS M&O 1999, all) is the basis for the information provided in this section.

3.1.2.1 Air Quality

Air quality is determined by measuring concentrations of certain pollutants in the atmosphere. The U.S. Environmental Protection Agency designates an area as being *in attainment* for a particular pollutant if *ambient* concentrations of that pollutant are below National *Ambient Air Quality Standards* (Table 3-5). (*Ambient air* is that part of the atmosphere outside buildings to which the general public has access.) The Environmental Protection Agency established the national standards, as directed by the Clean Air Act, to define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). The standards specify the maximum pollutant concentrations and frequencies of occurrence for specific averaging periods.

Areas in violation of one or more of these standards are called *nonattainment areas*. If there are not enough air quality data to determine the status of attainment of a remote or sparsely populated area, the area is listed as *unclassified*. For regulatory purposes, unclassified areas are considered to be in attainment.

Section 176(c)(1) of the Clean Air Act requires Federal agencies to ensure that their actions conform to applicable implementation plans for achieving and maintaining National Ambient Air Quality Standards for criteria pollutants. In addition, this section of the Act assigns primary oversight responsibility to the agencies, not to the Environmental Protection Agency or the States. Specifically, for there to be conformity, a Federal action must not contribute to new violations of standards for ambient air quality, increase the frequency or severity of existing violations, or delay timely attainment of standards in the area of concern (for example, a State or a smaller air quality region). The Environmental Protection Agency general conformity regulations (40 CFR 93, Subpart B) contain guidance for determining if a proposed Federal action would cause emissions to be above certain levels in locations designated as nonattainment or maintenance areas. In this case, a maintenance area is a region that was previously in nonattainment, but which has been redesignated to an attainment area with a requirement to develop a maintenance plan.

Table 3-5. National and Nevada ambient air quality standards.[a]

Pollutant	Primary and Secondary NAAQS,[b] except as noted: Period	Concentration	Highest measured Yucca Mountain concentration[c]	Nevada standards[d]
Sulfur dioxide	Annual[e]	0.03 part per million	0.002	Same
	24-hour[f]	0.14 part per million	0.002	
Sulfur dioxide (secondary)	3-hour[f]	0.5 part per million	0.002	
PM_{10}[g]	Annual[h]	50 micrograms per cubic meter	12	Same
	24-hour[i]	150 micrograms per cubic meter	67	
$PM_{2.5}$[j]	Annual[h]	15 micrograms per cubic meter	N/A[k]	None
	24-hour[l]	65 micrograms per cubic meter	N/A	
Carbon monoxide	8-hour[f]	9 parts per million	0.2	Same[m]
	1-hour[f]	35 parts per million	0.2	Same
Nitrogen dioxide	Annual[e]	0.053 part per million	0.002	Same
Ozone	1-hour[n]	0.12 part per million	0.1	Same
	8-hour[o]	0.08 part per million	N/A	None

a. Sources: 40 CFR 50.4 through 50.11; Nevada Administrative Code 445B.391.
b. NAAQS = National Ambient Air Quality Standard.
c. Units correspond to the units listed in the concentration column.
d. Nevada Administrative Code 445B.391.
e. Average not to be exceeded in the period shown.
f. Average not to be exceeded more than once in a calendar year.
g. PM_{10} = particulate matter with a diameter less than 10 micrometers (0.0004 inch). Until the revised State Implementation Plan is approved, 40 CFR 50.6 applies; then 40 CFR 50.7 would apply.
h. Expected annual arithmetic mean should be less than value shown.
i. Number of days per calendar year exceeding this value should be less than 1. Under 40 CFR 50.7, 99th-percentile value should be less than value shown.
j. $PM_{2.5}$ = particulate matter with a diameter less than 2.5 micrometers (0.0001 inch). Standard has not been implemented.
k. N/A = not available; no monitoring data has been collected since the new standard was implemented.
l. 98th-percentile value should be less than value shown.
m. The Nevada ambient air quality standard for carbon monoxide is 9 parts per million at less than 1,500 meters (4,900 feet) above mean sea level and 6 parts per million at or above 1,500 meters; Nevada Administrative Code 445B.31.
n. This standard was replaced in 1998 by 40 CFR 50.10 for all air quality regions of interest.
o. Standard promulgated in 1997, but not yet implemented due to court challenges. Three-year average of the fourth-highest monitored daily maximum 8-hour average concentration.

The quality of the air at the site of the proposed repository and the surrounding parts of the Nevada Test Site, Nellis Air Force Range (including southwestern Lincoln County), southwestern Esmeralda County, and southern Nye County is unclassified because there are limited air quality data (40 CFR 81.329). Data collected at the site indicate the air quality is within applicable standards. Portions of Clark County in the air quality region of influence are in attainment with the National Ambient Air Quality Standards. Inyo County, California, is in attainment with national and California ambient air quality standards for carbon monoxide, nitrogen dioxide, and sulfur dioxide. It is in attainment with the national *PM_{10} standard*, but in nonattainment with the more restrictive California standard (DIRS 103161-CEPA 1998, pp. H6 to H35). Outside the repository air quality region of influence, most of Nevada is unclassified and therefore in attainment. There are Nevada exceptions; Reno and Las Vegas are both in nonattainment for carbon monoxide and PM_{10} and the Lake Tahoe basin is in nonattainment for carbon monoxide. In addition, the Reno area is in nonattainment for ozone. Section 3.2.2 contains additional air quality information.

Air quality in attainment areas is controlled under the Prevention of Significant Deterioration program of the Clean Air Act, with the goal of preventing significant deterioration of existing air quality. Under the Prevention of Significant Deterioration provisions, Congress established a land classification scheme for areas of the country with air quality better than the National Ambient Air Quality Standards. Class I allows very little deterioration of air quality; Class II allows moderate deterioration; and Class III allows more deterioration; but in all cases the pollution concentrations shall not violate any of the National

Ambient Air Quality Standards. Congress designated certain areas as mandatory Class I, which precludes redesignation to a less restrictive class, to acknowledge the value of maintaining these areas in relatively pristine condition. Congress also protected other nationally important lands by originally designating them as Class II and restricting redesignation to Class I only.

All other areas were initially classified as Class II, and can be redesignated as either Class I or Class III. In the region of influence, all areas are designated as Class II. There are no Class I areas, although one area, the Death Valley National Park, is a national monument and a protected Class II area that could be redesignated as Class I (DIRS 148117-EPA 1998, all; DIRS 148119-EPA 1997, all). It is about 35 kilometers (22 miles) southwest of Yucca Mountain.

The construction and operation of a facility in an attainment area could be subject to the requirements of the Prevention of Significant Deterioration program if the facility received a classification as a major source of air pollutants. At present, the proposed repository site and the Nevada Test Site have no sources subject to those requirements (DIRS 101811-DOE 1996, p. 4-146).

As part of Yucca Mountain site characterization, DOE obtained an air quality operating permit from the State of Nevada (DIRS 104920-Del Porto 1996, all). The permit places specific operating conditions on various systems that DOE uses during site characterization activities. These conditions include limiting the emission of criteria pollutants, defining the number of hours a day and a year a system is allowed to operate, and determining the testing, monitoring, and recordkeeping required for the system.

In 1997, the Environmental Protection Agency issued new National Ambient Air Quality Standards for ozone and particulate matter. The new standard for particulate matter (40 CFR 50.7) includes fine particles in the respirable range with diameters smaller than 2.5 micrometers (see Table 3-5). The implementation of this new standard applies to all areas, but initial monitoring will focus on urban areas because (1) this pollutant comes primarily from combustion (auto exhaust, etc.) rather than *fugitive dust* sources (windblown dust, etc.) and (2) the first priority for monitoring programs is the assessment of densely populated areas. The new (1997) standard for ozone included revoking the 1-hour ozone standard for all counties in the United States with no current measured violations, including all of Nevada and the region around Yucca Mountain, and replacing it with a new 8-hour ozone standard. The new particulate and ozone standards were challenged in court and subsequently overturned by a Federal appeals court (DIRS 148090-American Trucking Associations v. U.S. Environmental Protection Agency 1999, all). As a result, the Environmental Protection Agency reinstated the 1-hour ozone standard in July 2000. However, early in 2001 the U.S. Supreme Court upheld the ability of the Environmental Protection Agency to set national air quality standards (DIRS 156704-Whitman v. American Trucking Associations 2001, all). Following its ruling, the Supreme Court remanded the case back to the appeals court to resolve all outstanding issues in light of its opinion. Implementation of the standards is delayed pending resolution of implementation details and some additional legal issues.

In 1989, DOE began monitoring particulate matter at the site of the proposed repository as part of site characterization activities and later as part of the Nevada Air Quality operating permit requirements. Concentration levels of inhalable particles smaller than 10 micrometers in diameter have been well below applicable National Ambient Air Quality Standards, with annual average concentrations 20 to 25 percent of the standard (see Table 3-5).

From October 1991 through September 1995, DOE monitored the site of the proposed repository for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) as part of site characterization. The concentration levels of each pollutant were well below the applicable National Ambient Air Quality Standards (see Table 3-5). In fact, concentrations of carbon monoxide and sulfur dioxide were not detectable during the entire monitoring period. Nitrogen dioxide was detected occasionally at concentrations of a few parts per billion (around 0.002 part per million) by volume, probably from nearby vehicle exhausts, about 4 percent of the applicable annual average standard (see Table 3-5). Ozone was the only criteria pollutant routinely detected; the maximum hourly concentrations were 0.081 to 0.096 part per million, which is 67 to 80 percent of the 1-hour regulatory standard. The source of the ozone has not been determined, but could be urban areas in southern California.

3.1.2.2 Climate

The Yucca Mountain region has a relatively arid climate, with annual precipitation totals ranging between approximately 10 and 25 centimeters (4 and 10 inches) per year (DIRS 101779-DOE 1998, Volume 1, p. 2-29). Precipitation at a given location depends on nearby topographic features. The winter season is mild, with some periods of below freezing temperatures. Occasional periods of persistent rain have produced more than 5 centimeters (2 inches) of rainfall in daily periods. The summer season is typically hot and dry, with occasional periods of monsoon thunderstorms producing locally large amounts of rain. Storms can produce more than 2.5 centimeters (1 inch) of rain in a matter of hours.

Mean nighttime and daytime air temperatures typically range from 22°C to 34°C (72°F to 93°F) in the summer and from 2°C to 10.5°C (34°F to 51°F) in the winter (DIRS 100117-CRWMS M&O 1997, pp. A-1 to A-16). Temperature extremes range from -15°C to 45°C (5°F to 113°F). On average, the daily range in temperature change is about 10°C (18°F). Higher elevations are cooler, though the coldest areas can be in canyons and washes to which heavy cold air flows at night. Relative humidity levels range from about 10 percent on summer afternoons to about 50 percent on winter mornings and to near 100 percent during precipitation events.

In the valleys, airflow is channeled by local topography, particularly at night during stable conditions (DIRS 100117-CRWMS M&O 1997, p. 4-13 to 4-16). With the exception of the nearby confining terrain, which includes washes and small canyons on the east side of Yucca Mountain, local wind patterns have a strong daily cycle of daytime winds from the south and nighttime winds from the north. Confined areas also have daily cycles, but the wind directions are along terrain axes, typically upslope in the daytime and downslope at night. Wind direction can also vary with height. As shown in Figure 3-3, the winds at a height of 60 meters (200 feet) show a strong north-south flow up and down the valley. The winds at 10 meters (33 feet) show a strong southerly flow, but at night the wind pattern reflects more of the drainage flow downslope from Yucca Mountain. Hourly average wind speeds are usually greater than 1.8 meters a second (4 miles an hour), indicating few calm periods. Over the entire monitoring network, the average wind speed ranges from 2.5 to 4.4 meters a second (5.6 to 9.8 miles an hour); the fastest 1-minute wind speeds range from 19 to 33 meters a second (42 to 74 miles an hour); and the peak gusts range from 26 to 38 meters a second (59 to 86 miles an hour). The highest wind speeds typically occur on exposed ridges.

Severe weather can occur in the region, usually in the form of summer thunderstorms. These storms can generate an abundant amount of lightning, strong winds, and heavy and rapid precipitation. Tornadoes can occur, though they are not a substantial threat in the region; four have been recorded within 240 kilometers (150 miles) of the site of the proposed repository during the past 53 years, and one occurred in 1987 in the Amargosa Desert about 50 kilometers (30 miles) south of the site (DIRS 100117-CRWMS M&O 1997, p. 4-26).

Paleoclimatology. Climate studies and analyses pursued as part of the Yucca Mountain project have also included paleoclimatology, which is the study of ancient climates. These studies looked at time scales as large as hundreds of millennia. The primary assumption associated with paleoclimatology efforts is that climate is cyclical so that past climates provide insight into potential future climates (DIRS 151945-CRWMS M&O 2000, p. 6.4-2). The efforts have incorporated studies of the Earth's orbital and global circulation parameters and how those parameters have affected ancient climates in the Yucca Mountain region. Orbital parameters include theories that the shape of the Earth's orbit and the "wobble"

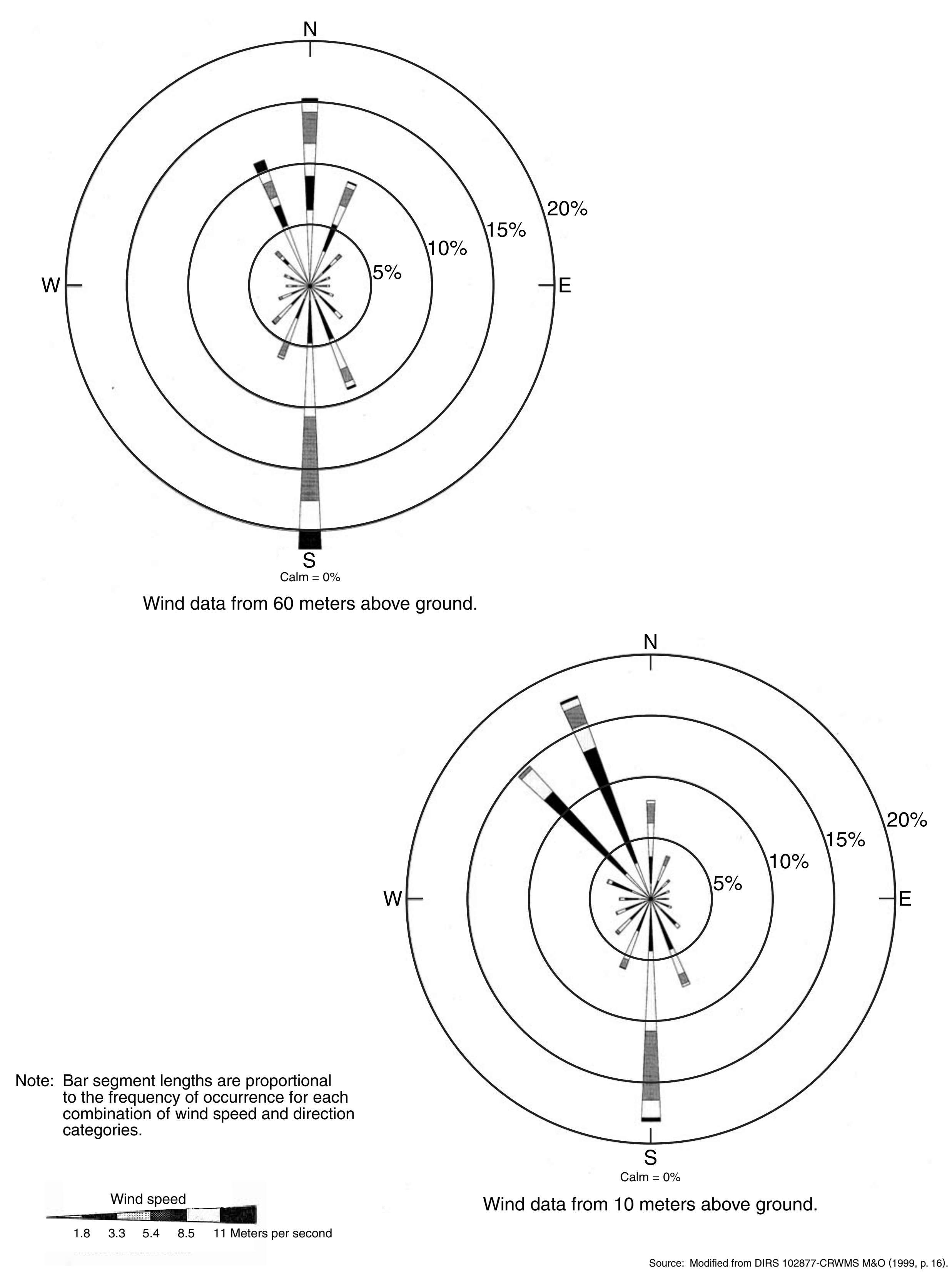

Figure 3-3. Wind rose plots for 10 and 60 meters (33 and 200 feet) above ground in the proposed repository facilities vicinity.

in its axial spin change in cycles that repeat over tens and hundreds of millennia (DIRS 151945-CRWMS M&O 2000, p. 6.3-4). Correlations have been made between these global position changes and long duration traces, or evidence, of paleoclimate conditions in the region. Two of the primary sources of this evidence are calcite deposited on the walls of rock fractures at Devils Hole in Nevada and lake deposits at the historic Owens Lake location in California. In these examples, analysis of residues left behind has provided insights into climate conditions as far back as 600,000 to 850,000 years ago (DIRS 151945-CRWMS M&O 2000, pp. 6.3-9 and 6.3-12).

Climate regimes believed to have existed in Yucca Mountain's past, and therefore that should occur in its future, have been grouped into the following categories: (1) a warm and dry, modern-like interglacial climate; (2) a warm and wet monsoon climate; (3) an intermediate glacial transition climate; and (4) glacial periods (DIRS 151945-CRWMS M&O 2000, pp. 6.4-11 and 6.4-17). The driest of these climate groupings is the modern-like interglacial climate and (as indicated by its name) represents the climate currently being experienced at Yucca Mountain. Characteristics of these climate regimes and postulated future durations are included as input parameters to the long-term performance assessment modeling performed for the site (DIRS 153246-CRWMS M&O 2000, pp. 3-38 to 3-42).

3.1.3 GEOLOGY

DOE has studied the existing physiographic setting (characteristic landforms), *stratigraphy* (rock strata), and geologic structure (structural features resulting from rock deformations) at Yucca Mountain and in the surrounding region. These studies have yielded detailed information about the surface and subsurface features in the region. This section describes the region of influence for geology, which includes the baseline conditions of the region's geology as well as the specific geology of Yucca Mountain. DOE investigated seismicity (*earthquake* activity) in the Yucca Mountain region; the investigations focused on understanding the Quaternary history of movement on faults in the region and the historic record of earthquake activity. The Department also investigated volcanoes in the Yucca Mountain region to assess the potential for volcanism to result in adverse effects to a repository. In addition, DOE considered the possibility that there might be minerals and energy resources at or near the site of the proposed repository.

3.1.3.1 Physiography (Characteristic Landforms)

Yucca Mountain is in the southern part of the *Great Basin* subprovince of the Basin and Range Physiographic Province (Figure 3-4), a region characterized by generally north-trending, linear mountain ranges separated by intervening valleys (basins) (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). The Great Basin encompasses nearly all of Nevada plus parts of Utah, Idaho, Oregon, and California. Mountain ranges of the Great Basin, including Yucca Mountain, are mostly tilted, fault-bounded crustal blocks that are as much as 80 kilometers (50 miles) long and 8 to 24 kilometers (5 to 15 miles) wide. Ranges typically rise from 300 to 1,500 meters (1,000 to 4,900 feet) above the adjacent valley floors and occupy 40 to 50 percent of the total land area (DIRS 151945-CRWMS M&O 2000, pp. 4.4-1 and 4.4-2).

Valleys between the mountain ranges are filled with alluvial sediments (deposits of sand, mud, and other such materials formed by flowing water) from the adjacent ranges. Many valleys are called *closed basins* because they, like the Great Basin on a regional scale, lack a drainage outlet (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). Water and sediment from adjacent ranges become trapped and move to the lowest part of such valleys to form a *playa*, a flat area that is largely vegetation-free owing to high salinity, which results from evaporation of the water. Valleys with drainage outlets have intermittent stream channels that carry eroded sediment to lower drainage areas.

The present landscape, distinguished by the broad series of elongated mountain ranges alternating with parallel valleys, is the result of past episodes of faulting that elevated the ranges above the adjacent valleys. Section 3.1.3.2 addresses such faulting. Yucca Mountain is an irregularly shaped volcanic

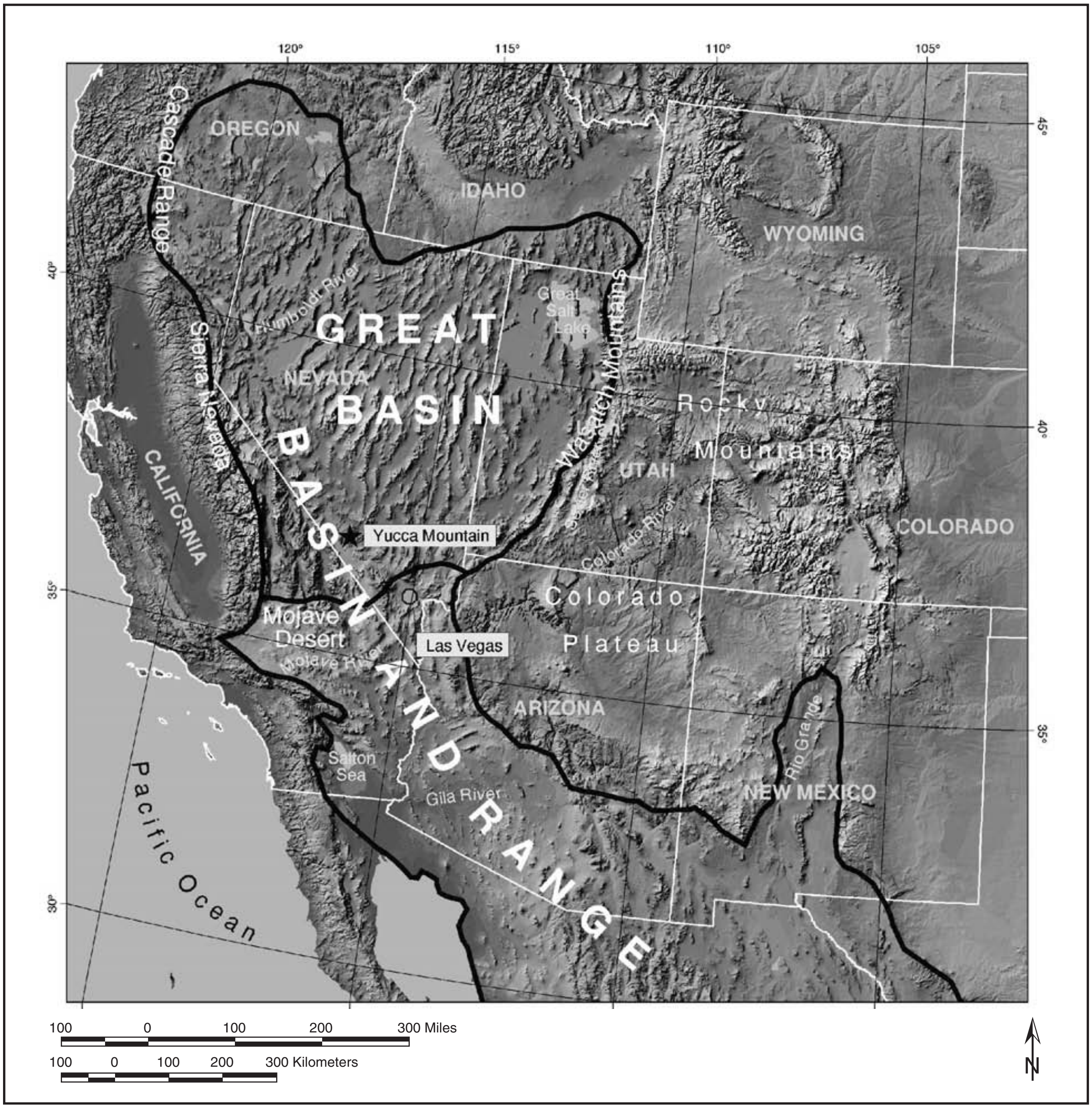

Figure 3-4. Basin and Range Physiographic Province and Great Basin Subprovince.

upland, 6 to 10 kilometers (4 to 6 miles) wide and 35 kilometers (22 miles) long (DIRS 151945-CRWMS M&O 2000, pp. 2.2-1 and 4.4). This mountain is part of a volcanic plateau formed between about 14 million and 11.5 million years ago (DIRS 100075-Sawyer et al. 1994, p. 1304) known as the Southwestern Nevada volcanic field. Although Yucca Mountain is a product of both volcanic activity and faulting, the region exhibits evidence of a complex history of *deformation* associated with past interactions of crustal segments (plates) (DIRS 151945-CRWMS M&O 2000, p. 4.2-1). Geologic relations indicate that many of the current features and the landscape in the Yucca Mountain region formed between 12.7 million and 11.7 million years ago (DIRS 151945-CRWMS M&O 2000, p. 4.4-2). Remnants of the Timber Mountain caldera (one of the centers of the southwestern Nevada volcanic field from which most of the volcanic rocks on the surface of Yucca Mountain were erupted) and other calderas are north of Yucca Mountain (see Figure 3-5).

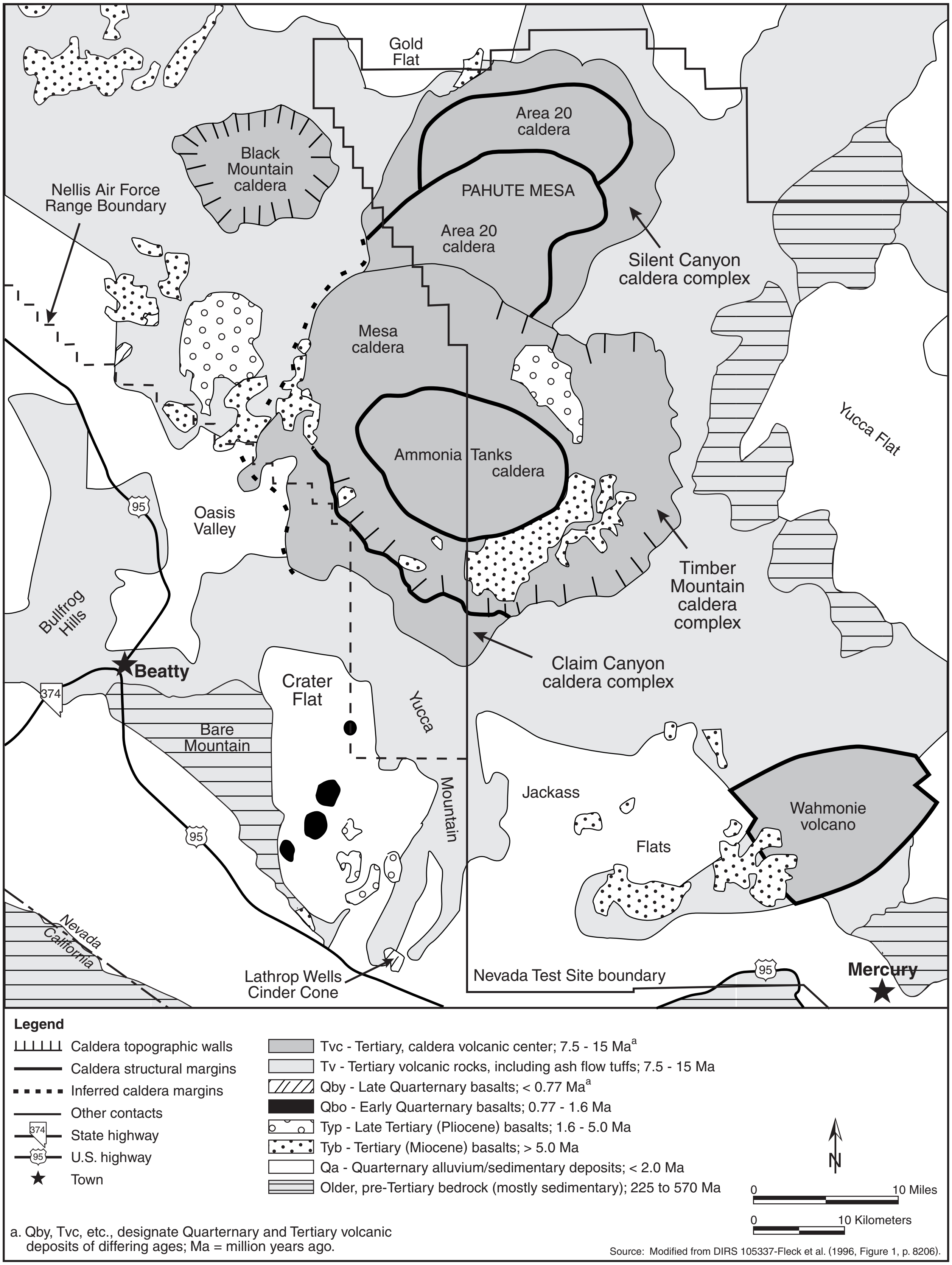

Figure 3-5. Simplified geologic map showing calderas of the southwest Nevada volcanic field in the Yucca Mountain vicinity.

Almost without exception, west-facing slopes at Yucca Mountain are steep and east-facing slopes are gentle, which expresses the underlying geologic structure (see Section 3.1.3.2). Small valleys eroded in the mountain are narrow, V-shaped drainages that flatten and broaden near the mountain base. The crest of Yucca Mountain reaches elevations from 1,500 meters (4,900 feet) to 1,900 meters (6,300 feet) above sea level. The bottoms of the adjacent valleys are approximately 650 meters (2,100 feet) lower (DIRS 151945-CRWMS M&O 2000, p. 4.4-4).

Yucca Mountain is bordered on the north by Pinnacles Ridge and *Beatty Wash*, on the west by *Crater Flat*, on the south by the Amargosa Desert, and on the east by the Calico Hills and by *Jackass Flats*, which contains *Fortymile Wash* (Figure 3-6). Beatty Wash is one of the largest tributaries of the Amargosa River and drains the region north and west of Pinnacles Ridge, including the northern end of Yucca Mountain.

Crater Flat (Figure 3-6) is an oval-shaped valley between Yucca Mountain and *Bare Mountain*. It contains four prominent volcanic cinder cones and related lava flows that rise above the valley floor. Crater Flat drains to the Amargosa River through a gap in the southern end of the basin.

Jackass Flats is an oval-shaped valley east of Yucca Mountain bordered by Yucca, Shoshone, Skull, and Little Skull Mountains (Figure 3-6). It drains southward to the *Amargosa River*. *Fortymile Wash* is the most prominent drainage through Jackass Flats to the Amargosa River.

Site Stratigraphy and Lithology

The exposed stratigraphic section at Yucca Mountain is dominated by mid-Tertiary volcanic ash-flow and ash-fall deposits with minor lava flows and reworked materials. These deposits originated in the calderas shown in Figure 3-5. Regionally, the thick series of volcanic rocks that form Yucca Mountain overlies *Paleozoic* sedimentary rocks that are largely of marine origin. The volcanic rocks, in turn, are covered in many areas by a variety of late Tertiary and Quaternary surficial deposits (DIRS 151945-CRWMS M&O 2000, p. 4.5-1). The stratigraphic section is summarized in Table 3-6, which depicts rock assemblages according to the geologic age during which they were deposited. The stratigraphic sequence of the Yucca Mountain area consists, from oldest to youngest, of Pre-Cenozoic (that is, Paleozoic and Precambrian) sedimentary and metasedimentary (sedimentary rocks that have been altered by metamorphism), mid-Tertiary siliceous (rich in silica) volcanic rocks, Tertiary to Quaternary basalts, and late Tertiary to late Quaternary surficial deposits.

Only Tertiary and younger rocks are exposed at Yucca Mountain (DIRS 151945-CRWMS M&O 2000, p. 4.5-1). Parts of the older (Pre-Cenozoic) rock assemblages described in Table 3-6 are exposed at Bare Mountain, the Calico Hills, and the Striped Hills, to the east, northeast, and southeast of Yucca Mountain, respectively (see Figure 3-6) (DIRS 151945-CRWMS M&O 2000, Figures 4.2-3 to 4.2-6, pp. F4.2-3 to F4.2-6). Many of these older rocks are widespread in the Great Basin where their cumulative thickness is thousands of feet. Detailed information about their characteristics is lacking at Yucca Mountain because only one *borehole*, about 2 kilometers (1.2 miles) east of Yucca Mountain, has penetrated these rocks. Paleozoic carbonate rocks were penetrated in this borehole at a depth of about 1,250 meters (4,100 feet) (DIRS 102046-Carr et al. 1986, p. 5-5). Paleozoic carbonate rocks form important aquifers in southern Nevada (DIRS 101167-Winograd and Thordarson 1975, all).

Table 3-7 lists the principal mid-Tertiary volcanic stratigraphic units mapped at the surface, encountered in boreholes, and examined in the Exploratory Studies Facility that have been a major focus of site characterization investigations. The proposed repository and access to it would be entirely in the Paintbrush Group, so investigations have focused particularly on the formations in that stratigraphic unit. Detailed descriptions of the volcanic stratigraphic units are in the Yucca Mountain Project Stratigraphic Compendium (DIRS 101535-CRWMS M&O 1996, all). The following paragraphs provide a general

Table 3-6. Highly generalized stratigraphy summary for the Yucca Mountain region.[a]

Geologic age designation	Major rock types (lithologies)
Cenozoic Era	
Quaternary Period (< 1.6 Ma)[b]	Alluvium; basalt
Tertiary Period (< 65 - 1.6 Ma)	Silicic ash-flow tuffs; minor basalts. Predominantly volcanic rocks of the southwestern Nevada volcanic field (includes Topopah Spring Tuff, host rock for the potential repository). Table 3-7 lists major Tertiary volcanic formations at Yucca Mountain.
Mesozoic Era (240 - 65 Ma)	No rocks of this age found in Yucca Mountain region.
Paleozoic Era (570 - 240 Ma)	Three major lithologic groups (lithosomes) predominate: a lower (older) carbonate (limestone, dolomite) lithosome deposited during the Cambrian through Devonian Periods (see Figure 3-17), a middle fine-grained clastic lithosome (shale, sandstone) formed during the Mississippian Period, and an upper (younger) carbonate lithosome formed during the Pennsylvanian and Permian Periods.
Precambrian Era (> 570 Ma)	Quartzite, conglomerates, shale, limestone, and dolomite that overlie older igneous and metamorphic rocks that form the crystalline "basement."

a. Source: Adapted from DIRS 151945-CRWMS M&O (2000, pp. 4.2-3 to 4.2-20).
b. Ma = approximate years ago in millions.

summary based on the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, pp. 4.5-1 to 4.5-34).

The bulk of the volcanic sequence consists of tuffs. Volcanic rocks known as ash-flow tuffs (or *pyroclastic* flow deposits) form when a hot mixture of volcanic gas and ash violently erupts and flows.

As the ash settles, it is subjected to various degrees of compaction and fusion depending on temperature and pressure conditions. If the temperature is high enough, glass and pumice fragments are compressed and fused to produce welded tuff (a hard, brick-like rock with very little open pore space in the rock *matrix*). Nonwelded tuffs, compacted and consolidated at lower temperatures, are less dense and brittle and generally have greater porosity. Ash-fall tuffs are formed from ash that cooled before settling on the ground surface, and bedded tuffs are composed of ash that has been reworked by stream action. All of these are found in the volcanic assemblage at Yucca Mountain.

In general, characterization of the various volcanic units is based on changes in depositional features, the development of zones of welding and devitrification (crystallization of glassy material), and the development of alteration products in some rocks. Mineral and chemical composition and properties such as density and porosity also have been used in distinguishing some units. Most of the formations listed in Table 3-7 contain phenocrysts (mineral grains distinctly larger than the surrounding rock matrix) and lithic clasts (rock fragments), have some part that is at least partially welded, and typically have some part that has devitrified during cooling of the deposit. In addition, the vitric (glassy) parts of many formations have been partly altered to clay and *zeolite* minerals, and all the rocks have developed various amounts of fractures, some of which contain secondary mineral fillings.

Lithophysal cavities are prominent features in some units, notably in the Tiva Canyon and Topopah Spring Tuffs, where they range from 1 to 50 centimeters (0.4 to 20 inches) in diameter and are a basis for the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

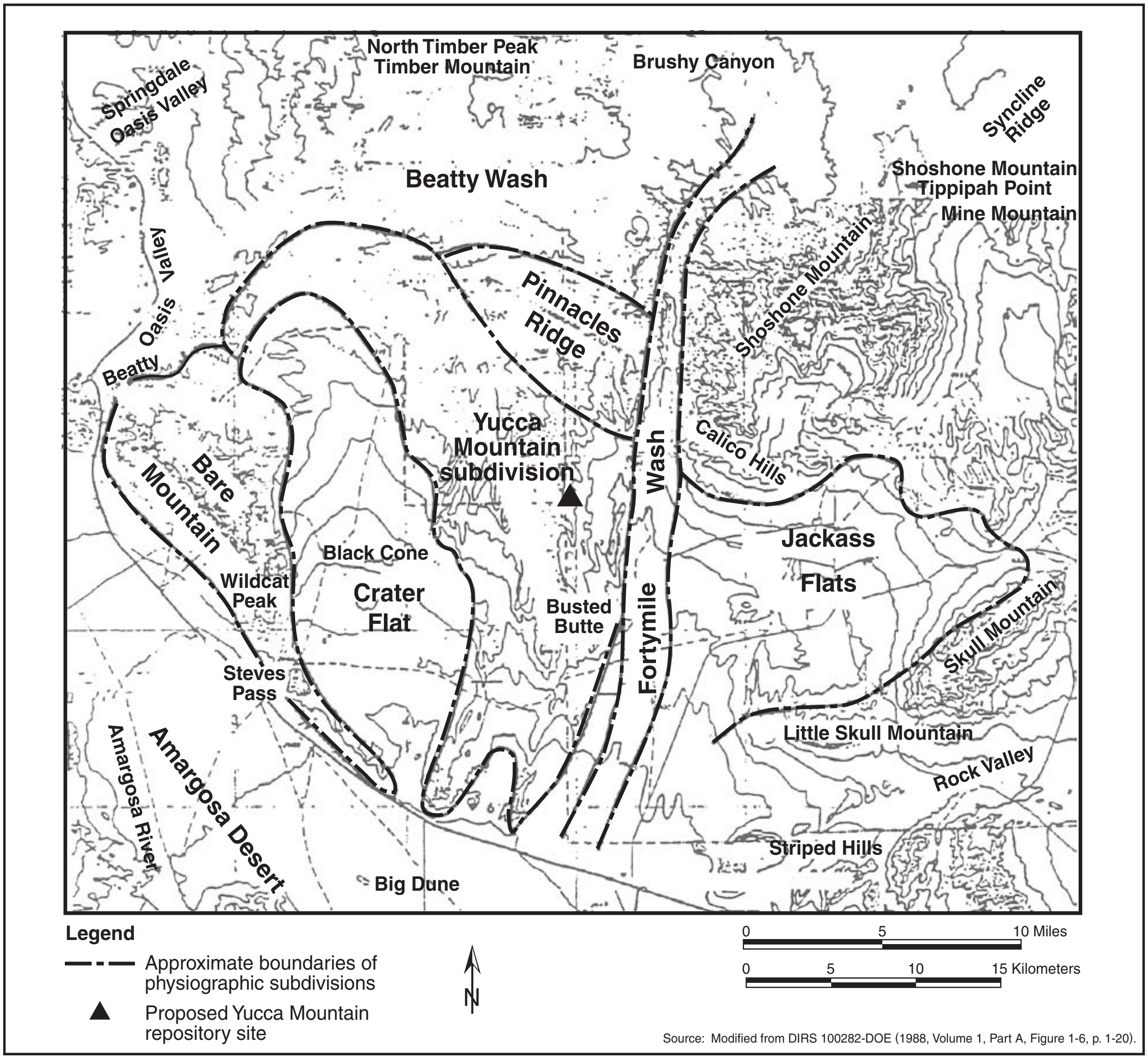

Figure 3-6. Physiographic subdivisions in the Yucca Mountain vicinity.

Although welded tuffs dominate the volcanic sequence, bedded tuffs are present in the Paintbrush Group and in some older parts of the sequence (DIRS 151945-CRWMS M&O 2000, Figures 4.5-3 and 4.5-4, pp. F4.5-3 to F4.5-4). Joints and fractures are common in the welded tuffs, producing much greater bulk permeabilities than those of the nonwelded and bedded tuffs (DIRS 151945-CRWMS M&O 2000, p. 4.10-6). This is an important distinction with regard to investigation of hydrologic conditions.

Some parts of the volcanic formations contain secondary mineral products created by alteration of the original materials after their original deposition and consolidation. Some alteration has resulted from reactions with groundwater, and the types of new mineral substances found can differ based on occurrence below or above the water table. Alteration products such as clay minerals and zeolites occur in several parts of the volcanic sequence; in some places, in-filling with zeolites has reduced the porosity and thus affected hydrologic properties. In most of the formations, contacts between vitric and devitrified layers are commonly marked by an interval containing clay or zeolite alteration minerals. A notable example is the interval, as much as several meters thick, where glassy rock at the base of the Topopah

Table 3-7. Tertiary volcanic rock sequence at Yucca Mountain.[a]

Name	Age (millions of years)[b]	Thickness (meters)[c]	Characteristics
Timber Mountain Group			
• Ammonia Tanks Tuff	11.5	Up to 215	Welded to nonwelded rhyolite tuff; exposed in southern Crater Flat.
• Rainier Mesa Tuff	11.6	< 30 - 240	Nonwelded to moderately welded vitric to devitrified tuff exposed locally along downthrown sides of large normal faults.
Post-Tiva Canyon, pre-Rainier Mesa Tuffs	12.5	0 - 61	Pyroclastic flows and fallout tephra deposits in subsurface along east flank of Yucca Mountain.
Paintbrush Group			Four formations (below) interlayered locally with lava flows and reworked volcanic deposits.
• Tiva Canyon Tuff	12.7	< 50 - 175	Crystal-rich to crystal-poor densely welded rhyolite tuff that forms most rock at surface of Yucca Mountain.
• Yucca Mountain Tuff	--[d]	0 - 45	Mostly nonwelded tuff but is partially to densely welded where it thickens to north and west.
• Pah Canyon Tuff	--	0 - 70	Northward-thickening nonwelded to moderately welded tuff with pumice fragments.
• Topopah Spring Tuff	12.8	Up to 380	Rhyolite tuff divided into upper crystal-rich member and lower crystal-poor member. Each member contains variations in lithophysal content, zones of crystallization, and fracture density. Glassy unit (vitrophyre) present at the base. Proposed host for repository.
Calico Hills Formation	12.9	15 - 460	Northward-thickening series of pyroclastic flows, fallout deposits, lavas, and basal sandstone; abundant zeolites except where entire formation is vitric in southwest part of central block of Yucca Mountain.
Crater Flat Group			Pyroclastic flows and interbedded tuffs of rhyolitic composition distinguished by abundance of quartz and biotite.
• Prow Pass Tuff	13.1	60 - 228	Sequence of variably welded pyroclastic deposits.
• Bullfrog Tuff	13.3	76 - 275	Partially welded, zeolitic upper and lower parts separated by a central densely welded tuff.
• Tram Tuff	13.5	60 - 396	Lower lithic-rich unit overlain by upper lithic-poor unit.
Lithic Ridge Tuff	13.9	185 - 304	Southward thickening wedge of welded and nonwelded pyroclastic flows and interbedded tuff extensively altered to clays and zeolites.
Pre-Lithic Ridge	+14.0	45 - 350	Mostly altered pyroclastic flows, lavas, and bedded tuff of rhyolitic composition.

a. Modified from DIRS 151945-CRWMS M&O (2000, pp. 4.5-19 to 4.5-33).
b. Source: DIRS 151945-CRWMS M&O (2000, Table 4.2-3, p. T4.2-3).
c. To convert meters to feet, multiply by 3.208.
d. -- = no absolute dates.

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the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

Spring Tuff (the basal *vitrophyre*) is in contact with the overlying nonlithophysal zone; this interval of alteration occurs in most boreholes in the vicinity of the proposed site (DIRS 151945-CRWMS M&O 2000, p. 4.5-11). Subtle differences in geochemical conditions are believed to have given rise locally over short distances to some unusual zeolites. One in particular is the fibrous zeolite *erionite*, which is a potential human health hazard (see Section 3.1.8.3). Data from rock samples show that in the potential repository horizon erionite, if it occurs, is either in the altered zone immediately above the Topopah Spring lower vitrophyre or in the moderately welded zone underlying this vitrophyre. It has also been identified in the lower Tiva Canyon Tuff (DIRS 101779-DOE 1998, Volume 1, p. 2-25).

Figure 3-7 is a geologic map that shows the surficial distribution of Tertiary volcanic units and younger surficial deposits in the vicinity of the proposed site. Figure 3-8 is a vertical cross-section through the southern part of this area that shows the subsurface expression of the mapped units, including structural aspects (east-dipping rock units and predominantly west-dipping normal faults). Examples of Tertiary units include the lava flows that cap Skull and Little Skull Mountains at the south and southeast margins of Jackass Flats, a *basalt* ridge that forms the southern boundary of Crater Flat, and a basaltic dike dated at 10 million years (DIRS 151945-CRWMS M&O 2000, p. 4.5-33) that intrudes in the northern part of the Solitario Canyon fault, which bounds the west flank of Yucca Mountain. Volcanic rocks younger than the Tertiary units occur locally at and in the Yucca Mountain vicinity but are of limited extent (Figure 3-5). They represent low-volume eruptions typically consisting of a single main cone surrounded by a small field of basalt flows. A north-trending series of cinder cones and lava flows on the southeast side of Crater Flat has been dated at 3.7 million years, and in the center of Crater Flat a series of four northeast-trending cinder cones (Qbo in Figure 3-5) has been dated at about 1 million years. The youngest basaltic center is the Lathrop Wells center, which is a single cone estimated to be 80,000 years old, with several different age dating methods putting the age between 70,000 and 90,000 years (DIRS 151945-CRWMS M&O 2000, p. 12.2-5). Some authors, however, cite evidence for *polycyclic volcanism*, suggesting a significant time interval between the emplacement of the Lathrop Wells *scoria* deposits.

The youngest stratigraphic units at Yucca Mountain are the predominantly unconsolidated surficial deposits of late Tertiary and Quaternary age. They are shown in Figure 3-7 as *alluvium* (material such as sand, silt, clay, pebbles, cobbles, or even boulders deposited on land by water) and *colluvium* (loose earth material that has accumulated at the base of a hill through the action of gravity) but have been classified in more detail as stream (alluvial) deposits, hillslope (colluvial) deposits, spring deposits, and windblown (eolian) deposits (DIRS 151945-CRWMS M&O 2000, pp. 4.4-10 to 4.4-21). Most Quaternary units exposed at the surface were deposited during the last 100,000 years (DIRS 101779-DOE 1998, Volume 1, p. 2-26). The bulk of these consist of alluvium deposited by intermittent streams that transported rock debris from hillslopes to adjacent washes and valleys.

Selection of Repository Host Rock

Selection of the potential repository emplacement area was based on several considerations, which include (1) depth below the ground surface sufficient to protect *nuclear waste* from exposure to the environment, (2) extent and characteristics of the host rock, (3) location away from major faults that could adversely affect the stability of underground openings or act as pathways for water flow that could eventually lead to radionuclide release, and (4) location of the water table in relation to the proposed repository (DIRS 104956-CRWMS M&O 1993, pp. 5-99 to 5-101).

DOE selected the middle to lower portion of the Topopah Spring Tuff as the potential repository horizon. The rock is strongly welded with variable *fracture* density and void space; experience gained from the

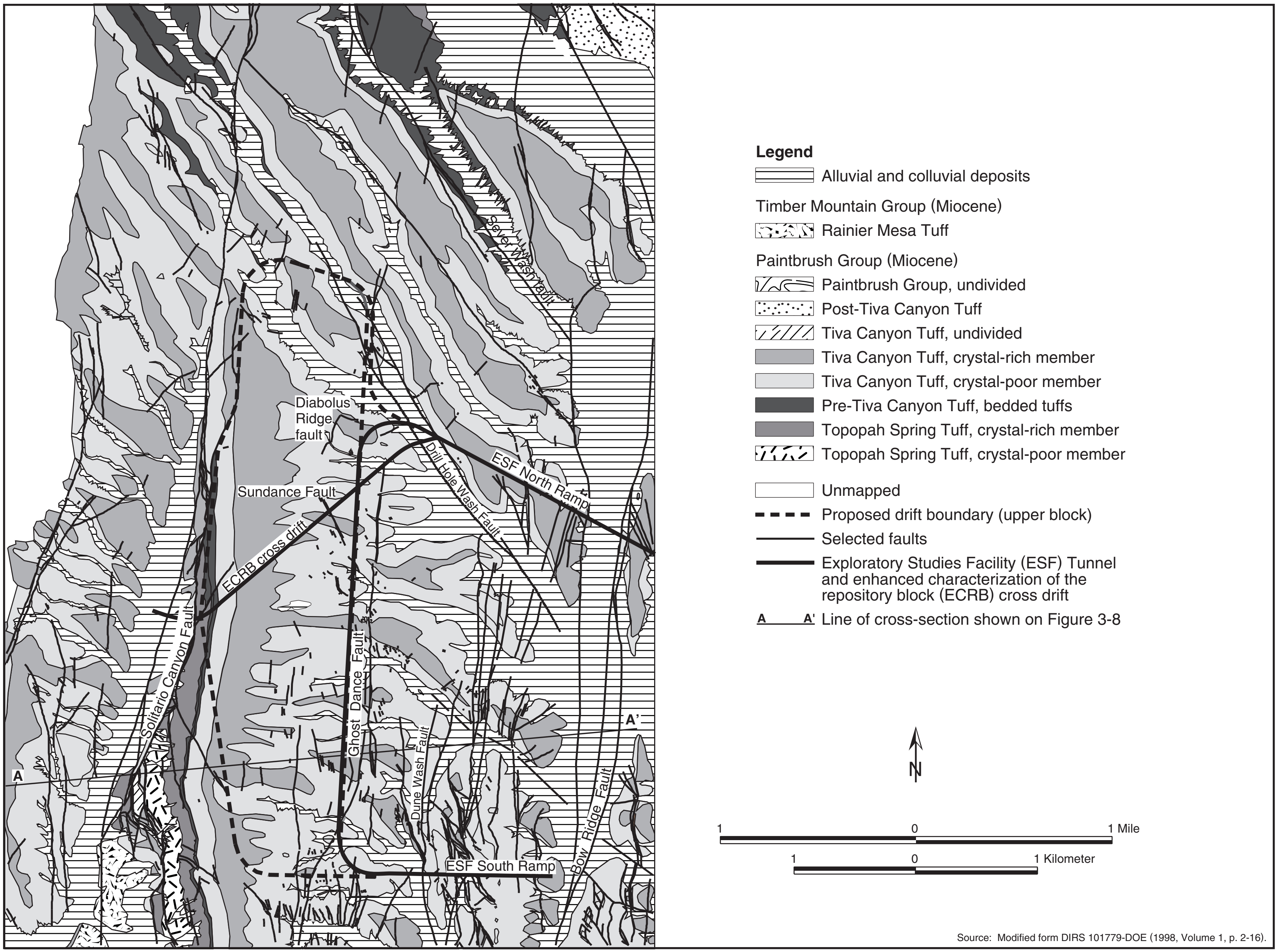

Figure 3-7. General bedrock geology of the proposed repository Central Block Area.

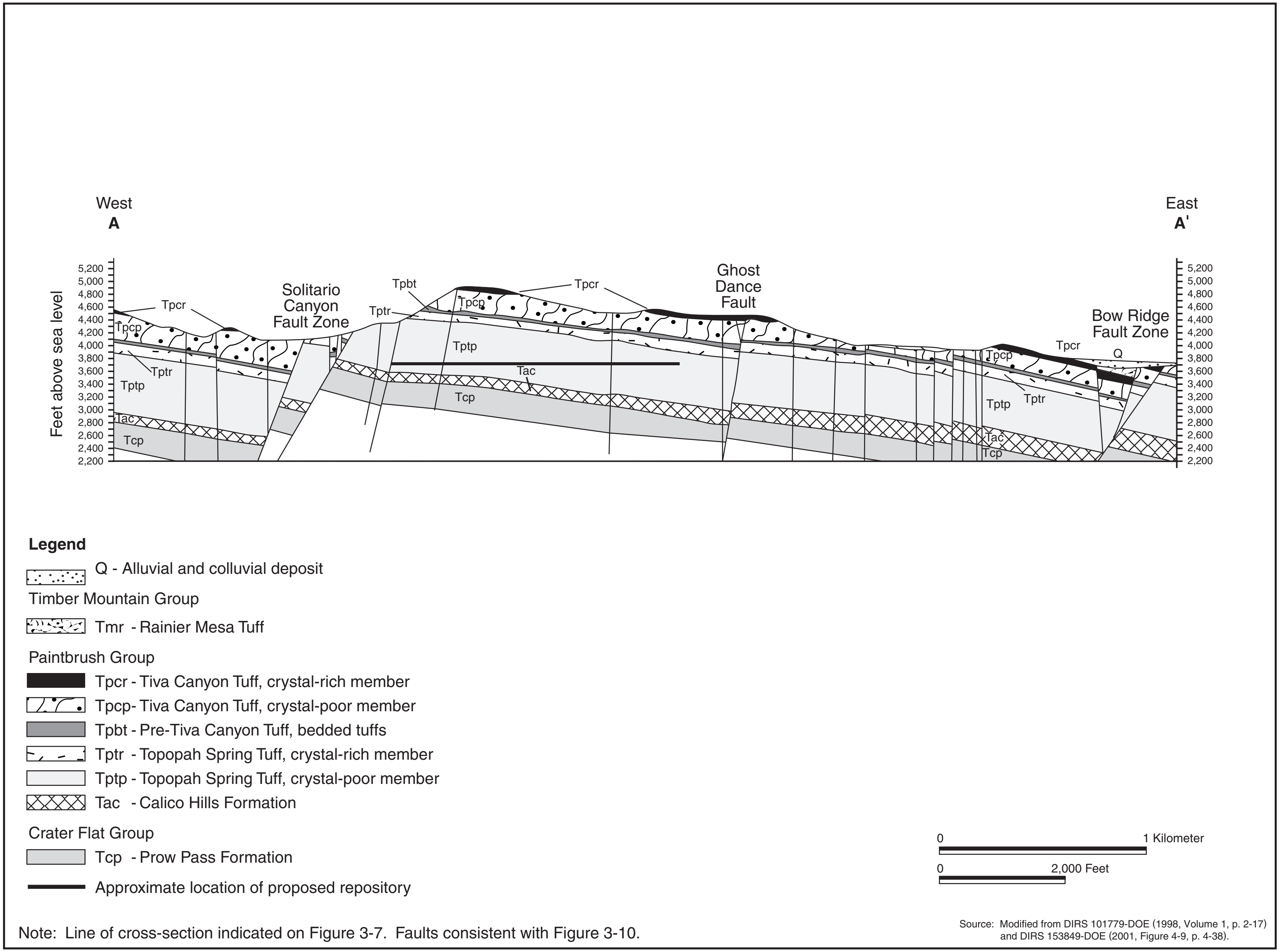

Figure 3-8. Simplified geologic cross-section of Yucca Mountain, west to east.

excavation of the Exploratory Studies Facility shows the capability to construct stable openings in this rock. Thermal and mechanical properties of this section of rock should enable it to accommodate the range of temperatures anticipated (thermal properties will not be affected greatly by construction and operation, as compared to postemplacement), and the identified repository volume is between major faults. Finally, the selected repository horizon is well above the present groundwater table. Based on geologic evidence the water table under Yucca Mountain has not been more than about 120 meters (390 feet) higher than its present level in the past several hundred thousand years; at such levels the water table would still be about 40 to 280 meters (130 to 920 feet) below the selected repository horizon (DIRS 151945-CRWMS M&O 2000, p. 9.4-1). Section 3.1.4 discusses the water table level further.

Potential for Volcanism at the Yucca Mountain Site

DOE has performed extensive investigations to determine the ages and nature of the volcanic episodes that produced the rocks described above (DIRS 151945-CRWMS M&O 2000, Chapters 4, 5, and 12). The rocks that form the southwestern Nevada volcanic field, characterized by large-volume silicic ash flows (including the host rock for the proposed repository), were erupted during a period of intense tectonic activity associated with active geologic faulting (DIRS 100075-Sawyer et al. 1994, all). The volcanism that produced these ash flows is complete (has not occurred in the region for more than 7.5 million years) and, based on the geology of similar volcanic systems in the Great Basin, no additional large-volume silicic activity is likely (DIRS 101779-DOE 1998, Volume 1, p. 2-85).

Basaltic volcanism in the Yucca Mountain region began about 11 million years ago as silicic eruptions waned and continued as recently as about 80,000 years ago. Basaltic volcanic events were much smaller in magnitude and less explosive than the events that produced the ash flows mentioned above. Typical products are the small volcanoes or cinder cones and associated lava flows in Crater Flat (about 1 million years old) and the Lathrop Wells volcano (possibly as young as 80,000 years) (DIRS 151945-CRWMS M&O 2000, p. 4.2-19). The potential for future volcanic activity in the Yucca Mountain region would be associated with basaltic volcanism rather than silicic activity.

Differing views on the likelihood of volcanism near Yucca Mountain result from uncertainties in the hazard assessment. To address these uncertainties, DOE has performed analyses, conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts, representing other Federal agencies (for example, the U.S. Geological Survey), national laboratories, and universities (for example, the University of Nevada and Stanford University). In 1995 and 1996, a panel of 10 scientists from these agencies and institutions and with expertise in volcanism reviewed the extensive information on volcanic activity in the Yucca Mountain vicinity and assessed the likelihood that future volcanic activity could occur at or in the vicinity of the repository (DIRS 151945-CRWMS M&O 2000, p. 12.2-21).

The probability of basaltic lava intruding into the repository is expressed as the annual probability that a volcanic event would disrupt (intersect) a repository, given that a volcanic event would occur during the period of concern. The expert panel assessed uncertainties associated with the data and models used to evaluate the potential for disruption of the potential Yucca Mountain Repository by a volcanic intrusion (dike) (DIRS 100116-CRWMS M&O 1996, all). The panel estimated the probability of a dike disrupting the repository during the first 10,000 years after closure to be 1 chance in 7,000. The estimate was recalculated to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 (with 5th and 95th percentiles of 1 chance in 130,000 and 1 chance in 2000, respectively, of a volcanic dike disrupting the repository) during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000, pp. 12.2-27 and 12.2-28 and Table 12.2-8).

3.1.3.2 Geologic Structure

Geologic structures (folds, faults, etc.) are features that result from deformation of rocks after their original formation. The present-day geologic structure of the Great Basin, including the Yucca Mountain region, is the cumulative product of multiple episodes of deformation caused by both compression and extension (stretching) of the Earth's crust.

Major east-west crustal compression occurred periodically in the Great Basin between about 350 million and 65 million years ago (DIRS 151945-CRWMS M&O 2000, pp. 4.2-21 and 4.2-27). This compression moved large sheets of older rock great distances upward and eastward over younger rocks (for example, thrust faults) to produce mountains. During the last 20 million years, crustal extension has resulted in the pattern of elongated mountain ranges and intervening basins (DIRS 151945-CRWMS M&O 2000, pp. 4.2-27 and 4.2-28). Crustal extension has resulted in vertical, lateral, and oblique movements (Figure 3-9). By about 11.5 million years ago the present mountains and valleys were well developed (DIRS 104181-Scott and Bonk 1984, all; DIRS 101557-Day et al. 1998, all).

Figure 3-7 shows the bedrock geology at the Yucca Mountain site and Figure 3-8 shows geologic structure. Figure 3-10 shows the surface traces of faults and their characteristic northerly alignment.

The crustal extension during the last 20 million years fractured the crust along the generally north-trending normal faults. Some of the crustal blocks were downdropped and tilted by movement along their bounding faults (called block-bounding faults). The estimated total displacement along the major north-trending block-bounding faults during the last 12 million years ranges from less than 100 meters (330 feet) to greater than 500 meters (1,600 feet) (DIRS 151945-CRWMS M&O 2000, pp. 12.3-38 to 12.3-58).

Measurements of Quaternary (1.6 million years to present) displacement reported on these faults range from 0 to 6 meters (0 to 20 feet), with most displacement in the 1-to-2.5-meter (3.3-to-8.2-foot) range (DIRS 101929-Simonds et al. 1995, Table 2). Displacements along faults are characterized in terms of the amount of movement per seismic event. For the set of faults of primary significance to the Yucca Mountain site, these values range from 0 to 1.7 meters (0 to 5.6 feet) per event (Table 3-8).

Table 3-8 lists the characteristics of the faults that are important to an understanding of seismic hazards to the potential repository. The Solitario Canyon fault along the west side of Yucca Mountain and the Bow Ridge Fault along the east side are the major block-bounding faults that bracket the area under consideration for the proposed repository. The proposed repository has been configured so that there would be no block-bounding faults in the emplacement zone.

Between the major north-trending, block-bounding faults there are *intrablock* or *subsidiary faults*. One intrablock fault, called the Ghost Dance fault, is in the area of the proposed repository. The Ghost Dance fault has a near-vertical dip from the surface to the depth of the repository (DIRS 151945-CRWMS M&O 2000, p. 4.6-22). This fault crosses the Exploratory Studies Facility tunnel. There is no evidence of Quaternary movement along the Ghost Dance fault (Table 3-8). Within the repository block, there are many subsidiary northwest-trending faults with smaller displacements than the block-bounding faults (DIRS 104181-Scott and Bonk 1984, all). There is no clear evidence that displacements have occurred along these subsidiary faults during the last 1.6 million years (DIRS 101929-Simonds et al. 1995, all). One short northwest-trending subsidiary fault, called the Sundance fault, transects the potential repository area (Figure 3-10).

The faults described above are associated with well-defined fractures in the rock structure. In addition to these fault fractures where there is a displacement of the sides in relation to each other, there are also fractures along which no appreciable movement has occurred. These are called *joints*. In the Paintbrush

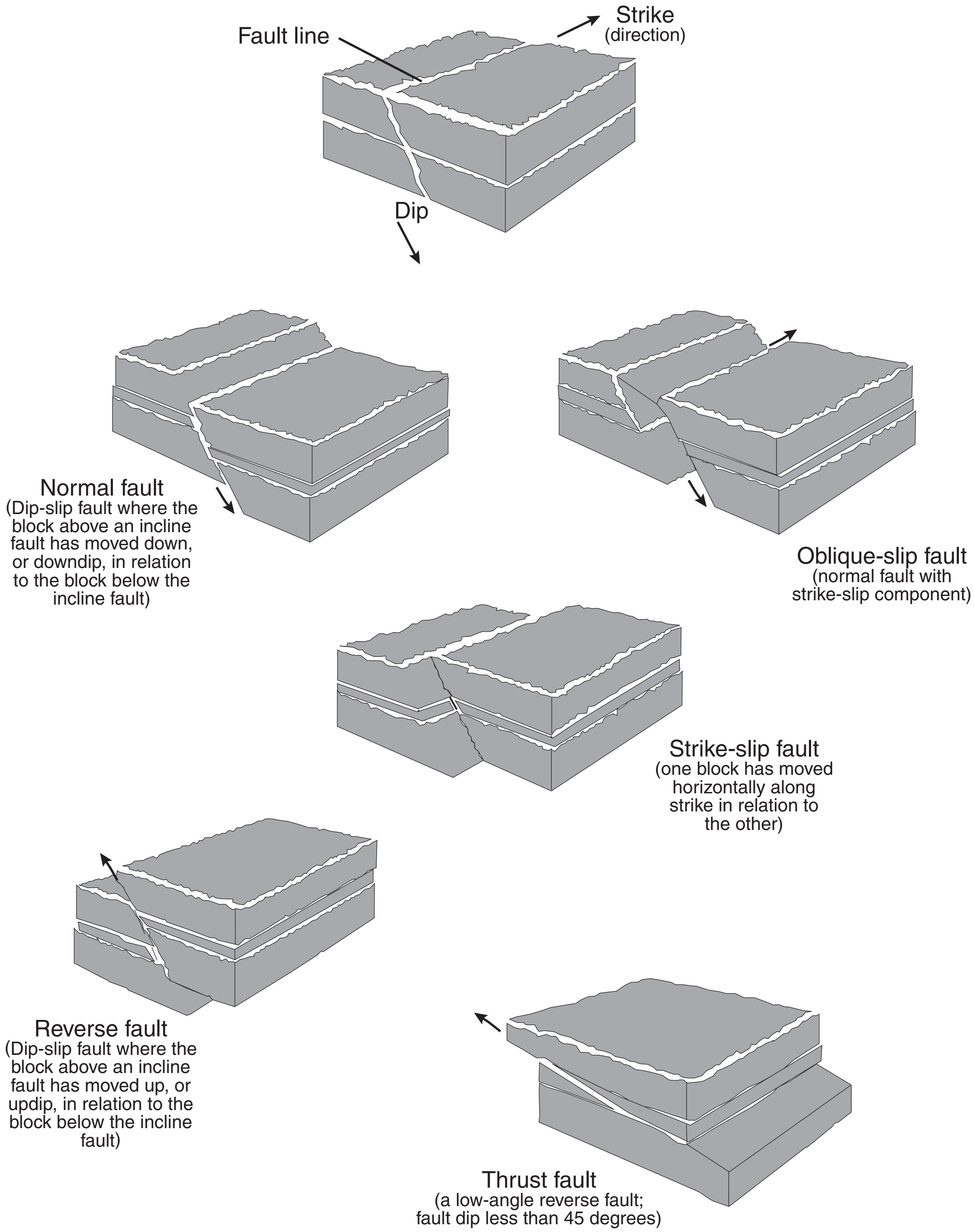

Figure 3-9. Types of geologic faults.

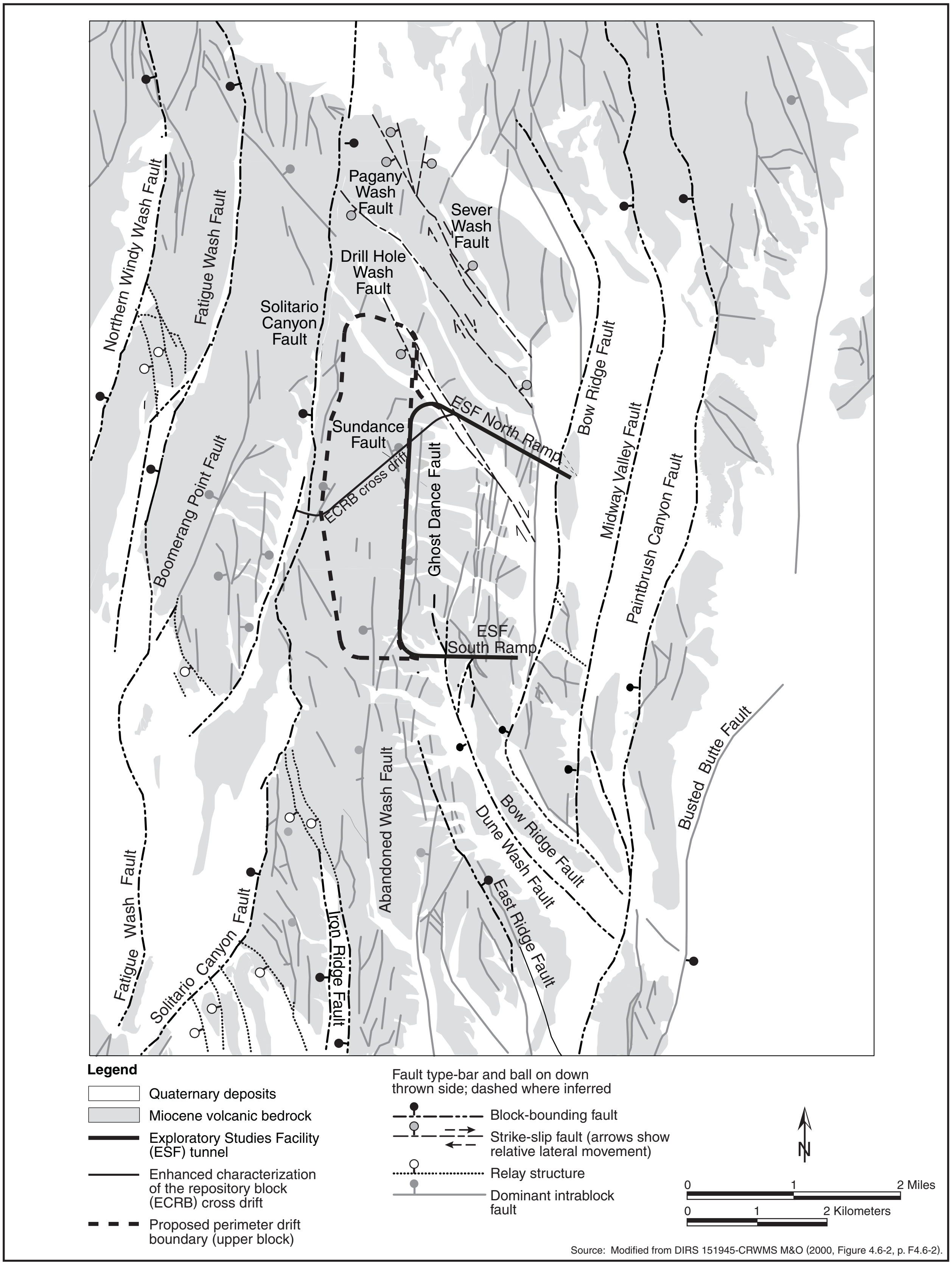

Figure 3-10. Mapped faults at Yucca Mountain and in the Yucca Mountain vicinity.

Table 3-8. Characteristics of major faults at Yucca Mountain.[a]

Fault	Surface features	Evidence of Quaternary displacement	Displacement per event[b] (meters)[c]	Total displacement; type of movement	Fault length (kilometers)[b] and dip
Crater Flat fault zone (north and south fault zones)	North zone has 2 faults 300-600 meters apart, bedrock faults and scarps, subtle scarps and lineaments in alluvium, bedrock/alluvium fault contacts.	3 of 3 trenches show multiple events; lineaments in alluvium, subtle scarps and fractures in alluvium.	0 - 0.5, north, 0.1-0.2, south	Total displacement unknown; oblique, left-lateral, west side down.	1 - 20 individual, 5 - 40 combined 70° west (north); 82° to 89° west (south)
Windy Wash fault[e]	Fault-line scarps in alluvium; bedrock/alluvium fault contacts; merges with Fatigue Wash fault.	3 of 3 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium	0.7	Less than 500 meters; mostly dip-slip, west side down	3 - 35; 77° west to vertical
Fatigue Wash fault[e]	Bedrock and alluvial scarps; fault-line scarps, lineaments in alluvium; merges with Windy Wash fault.	2 of 2 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0.3 - 1.3	75 meters; oblique left-lateral, west side down.	10 - 17; 73° west
Solitario Canyon fault[e]	Prominent fault-line scarp; discontinuous fault traces; subtle scarps in alluvium; southeastern splay is the Iron Ridge Fault.	6 of 11 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0 - 1.3	Increases southward from 0 to >500 meters; mostly normal with minor oblique left-lateral, down on east at north end, down on west at south end.	12.5 - 22; 72° west
Stagecoach Road fault	Prominent scarp and traceable faults in alluvium, merges with Solitario Canyon fault and (or) Paintbrush Canyon fault.	2 of 3 trenches show multiple events; fractures and scarps in alluvium; basalt ash in faulted alluvium.	0.4 - 0.7	400 to 600 meters; normal dip-slip to left oblique, west side down.	4 - 5 73° west
Ghost Dance fault zone[f]	Bedrock fault in zone of subparallel minor faults and breccia zones.	None	None	Increases southward from up to 5 meters at north end and 12-15 meters in central portion; dip-slip, west side down.	3 - 9; > 65° west
Bow Ridge fault[e]	Fault-line scarp along bedrock/alluvium contact; subtle lineaments; may merge along strike with Paintbrush Canyon fault.	3 of 7 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0.1 - 0.4	125 meters; oblique left-lateral, west side down.	6-10; 65° to 85° west
Midway Valley fault[e]	None, fault located on basis of geophysical evidence.	None	None in late Quaternary	40 - 60 meters; dip-slip, west side down.	1 - 5; west[g]
Paintbrush Canyon fault[e]	Bedrock and alluvial faults, scarps, and lineaments; possibly merges along strike with Stagecoach Road fault.	6 of 14 sites (10 trenches in Midway Valley and 4 exposures at Busted Butte) show multiple ruptures; basalt ash in fault plane; fractures in alluvium.	0.06 - 1.7	250 - 500 meters; dip-slip and oblique left-lateral, west side down.	10 - 26; 70° west
Northwest-trending faults[h] (not major faults)	Bedrock faults with local fault line scarps; most located by drilling and geophysical surveys.	None, with the exception of one trench across Pagany Wash fault showing absence of Quaternary displacement.	None (see column to left).	Undetermined; right-lateral to oblique right-lateral. (Except Dune Wash: 50-100 meters; normal, west side down.)	Undetermined; dip varies

a. Source: Modified from DIRS 106342-Menges and Whitney (1996, Table 4.2.1) with data from DIRS 151945-CRWMS M&O (2000, pp. 12.3-38 to 12.3-58; Tables 12.3-8a, -8b, and -9; pp. T12.3-7 to T12.3-19).
b. Preferred estimate of surface displacement associated with a prehistoric earthquake.
c. To convert meters to feet, multiply by 3.2808.
d. To convert kilometers to miles, multiply by 0.62137.
e. Block bounding fault.
f. Intrabock fault.
g. The dip and direction of this fault are uncertain.
h. Subsidiary northwest tending faults, includes the Pagany Wash, Sever Wash, Drill Hole Wash, and Dune Wash faults.

Group (Tiva Canyon, Yucca Mountain, Pah Canyon, and Topopah Spring tuffs), joints are subdivided into three groups based on their generating mechanism and time of occurrence: early cooling joints, later tectonic joints, and joints due to erosional unloading (DIRS 151945-CRWMS M&O 2000, pp. 4.7-5 to 4.7-7). Each type of joint exhibits different characteristics with respect to its length, orientation, and connectivity. The cooling and tectonic joints have similar orientations (generally running north-south), but cooling joints include irregularly spaced horizontal joints as well. Joints due to erosional unloading are variably oriented but tend predominantly east to west, cross-wise to the cooling and tectonic joints. Tectonic joints occur throughout the Paintbrush Group and cooling joints are identified in each of the welded units. In general, the highest joint frequencies and connectivities occur in the units of the Tiva Canyon and Topopah Spring tuffs and the lowest occur in the nonwelded Yucca Mountain and Pah Canyon tuffs. Most joints, particularly cooling joints, are confined to specific rock units and do not cross unit boundaries. They do not generally form through-going features like faults. Geologic, geoengineering, and hydrologic aspects of fractures are discussed in detail in the Yucca Mountain Site Description (DIRS 151945-CRWMS M&O 2000, pp. 4.6-17 to 4.6-19, 4.7-5 to 4.7-7, 4.7-36 to 4.7-40, and 8.9-1 to 8.9-15).

DOE identified and described alternative tectonic models to explain the current geologic structure resulting from past tectonic processes and deformation events that have affected the Yucca Mountain site. These models are described in the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Section 4.3), and were considered by the experts in the Probabilistic Seismic Hazard Analysis (DIRS 100354-USGS 1998, all) discussed below. Computer models provide a means of integrating data on volcanism, deposition, and fault movement, and include a representation of the existing geologic structures and the processes that operate at depth. Tectonic models provide a basis for evaluating the processes and events that could occur in the future and potentially affect the performance of a repository. The DOE hazard assessments used models that are supported by data.

3.1.3.3 Modern Seismic Activity

DOE has monitored seismic activity at the Nevada Test Site since 1978. The epicenters of many earthquakes that the Southern Great Basin Seismic Network has located within 20 kilometers (12 miles) of Yucca Mountain do not correlate with mapped surface traces of Quaternary faults (DIRS 151945-CRWMS M&O 2000, pp. 12.3-17 and 12.3-18). This lack of correlation is a common feature of earthquakes, particularly those of smaller magnitude, in the Great Basin and elsewhere. Earthquakes in the Yucca Mountain region have focal depths (the point of origin of an earthquake below the ground surface) ranging from near-surface to about 5 to 12 kilometers (3 to 7 miles) (DIRS 151945-CRWMS M&O 2000, p. 12.3-18). The earthquake focal mechanisms are *strike-slip* to normal *oblique-slip* along moderately to steeply dipping fault surfaces. These focal mechanisms indicate the nature of the fault planes on which the earthquakes occur, as shown in Figure 3-9.

The largest recorded historic earthquake within 50 kilometers (30 miles) of Yucca Mountain was the Little Skull Mountain earthquake in 1992 (DIRS 151945-CRWMS M&O 2000, p. 12.3-7 and Figure 12.3-4, p. F12.3-4), which had a Richter magnitude of 5.6 (DIRS 151945-CRWMS M&O 2000, p. 12.3-18). This seismic event occurred about 20 kilometers (12 miles) southeast of Yucca Mountain, about a day after the magnitude 7.3 earthquake at Landers, California, 300 kilometers (190 miles) south-southeast of Yucca Mountain. The Little Skull Mountain event caused no damage at Yucca Mountain, although some damage occurred at the Field Office Center in Jackass Flats (DIRS 151945-CRWMS M&O 2000, p. 12.3-18) about 5 kilometers (3 miles) north of the epicenter.

Seismic Hazard

DOE based the design ground motion and fault displacement that could be associated with future earthquakes at Yucca Mountain on the record of historic earthquakes in the Great Basin, evaluation of prehistoric earthquakes based on investigations (trenching and detailed mapping) of the faults at Yucca Mountain, and observation of ground motions associated with modern earthquakes using the Southern Great Basin Seismic Network.

Experts have evaluated site data and other relevant information (including differing models) to assess where and how often future earthquakes will occur, how large they will be, how much offset will occur at the Earth's surface, and how ground motion will diminish as a function of distance. Two panels of scientific experts conducted the Probabilistic Seismic Hazard Analysis (DIRS 100354-USGS 1998, all); one panel characterized sources of future earthquakes and their potential for surface fault displacement and the second addressed ground motion for the Yucca Mountain region. The results of this analysis are hazard curves that show the ground motions and potential fault displacements plotted with annual frequency of being exceeded. These are used to determine the design-basis ground motions and to assess the postclosure performance of the site (DIRS 151945-CRWMS M&O 2000, pp. 12.4-3 to 12.4-7). Figure H-1 in Appendix H shows the summary hazard curve for horizontal peak ground acceleration generated from the analysis.

The expert assessments indicate that geologic fault displacement hazard is generally low. For locations not on a major block-bounding fault, displacements greater than 0.1 centimeter (0.04 inch) will be exceeded an average of less than once in 100,000 years, whereas the mean displacements that are likely to be exceeded on the block-bounding Bow Ridge and Solitario Canyon faults are 7.8 and 32 centimeters (3.1 and 13 inches), respectively (DIRS 151945-CRWMS M&O 2000, p. 12.3-86). Mitigating potential fault displacement effects would involve avoiding faults in laying out repository facilities (DIRS 151945-CRWMS M&O 2000, p. 12.3-92).

Ground motion studies have investigated the level of shaking produced at Yucca Mountain by both local and regional earthquakes, and have estimated expected ground motion from hypothetical earthquakes. These predictions of probable ground motion amplitudes and frequencies support preliminary design requirements (the Exploratory Studies Facility), and future studies will provide additional site-specific information on soil and rock properties that will enable refinement of preliminary results and facilitate design analyses to mitigate seismic risk to a potential repository (DIRS 101779-DOE 1998, Volume 1, pp. 2-86 and 2-87).

The seismic design basis for the repository specifies that structures, systems, and components important to safety should be able to withstand the horizontal motion from an earthquake with a return frequency of once in 10,000 years (annual probability of occurrence of 0.0001) (DIRS 103237-CRWMS M&O 1998, p. VII-3). A recent comprehensive evaluation of the seismic hazards associated with the site of the proposed repository (DIRS 100354-USGS 1998, Figure 7-4) concluded that a 0.0001-per-year earthquake would produce peak horizontal accelerations at a reference rock site at Yucca Mountain of about 0.53*g* (mean value). DOE needs to complete additional investigations of ground motion site effects before it can produce the final seismic design basis for the surface facilities.

A recent study published in *Science* magazine (DIRS 103485-Wernicke et al. 1998, all) claims that the crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. If higher strain rates are present, the potential volcanic and seismic hazards would be underestimated on the basis of the long-term geologic record.

As part of the Yucca Mountain site characterization activities, DOE established a 14-station, 50-kilometer (30-mile), geodetic array, centered on Yucca Mountain, and conducted surveys in 1983, 1984, and 1993. As interpreted by U.S. Geological Survey researchers (DIRS 103457-Savage et al. 1994, all), the surveys indicated no large strain accumulation and thus do not support the claims in DIRS 103485-Wernicke et al. (1998, all). The Yucca Mountain array was resurveyed by the U.S. Geological Survey in 1998

(DIRS 118952-Savage, Svarc, and Prescott 1999, all). After correction for deformation associated with the Little Skull Mountain earthquake, the data continue to indicate a strain rate about an order of magnitude lower than that reported by DIRS 103485-Wernicke et al. (1998, all).

DOE is continuing to fund additional investigations on the crustal strain rate in the Yucca Mountain region through a grant to the University of Nevada. Dr. Wernicke of the California Institute of Technology (Cal Tech) continues to monitor conditions as a principal investigator under a subcontract, and a group at the University of Nevada at Reno is tasked with providing an independent evaluation of the assumptions and processing that support the Cal Tech results. This study involves 32 geodetic monument sites with continuous Global Positioning System measurements, a significant improvement over the study reported in *Science* in 1998. The first report (DIRS 156302-Marks 2001, all) from this effort was issued during 2001 and provided a status based on data collected through May 2001. According to the report, preliminary findings from this ongoing study are that strain is accumulating in the Yucca Mountain region, but at a notably lower rate than previously reported by DIRS 103485-Wernicke et al. (1998, all). Improved results are expected over the next year of the study, including a better characterization and explanation for the strain accumulation. DOE believes the results of this study will confirm the lower crustal strain rates as reported by the U.S. Geological Survey. However, if higher crustal strain rates are shown to exist, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

3.1.3.4 Mineral and Energy Resources

The southern Great Basin contains valuable or potentially valuable mineral and energy resources, including deposits with past or current production of gold, silver, mercury, base metals, and uranium. The proximity of known deposits and the identification of similar geologic features at Yucca Mountain have led some investigators to propose that the analyzed Yucca Mountain land withdrawal area (see Figure 3-2) could have the potential for mineral resources (DIRS 103483-Weiss, Noble, and Larson 1996, p. 5-26).

DOE site investigations included evaluation of the potential for mineral and energy resources in the analyzed withdrawal area because the presence of such resources could lead to exploration and inadvertent *human intrusion* (see Chapter 5). The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Section 4.9) describes results of investigations that address relevant natural resources. Site characterization investigators identified no economic deposits of base or precious metals, industrial rocks or minerals, and energy resources, based on present use, extraction technology, and economic value of the resources (DIRS 151945-CRWMS M&O 2000, p. 4.9-12 to 4.9-14). DOE believes the potential for economically useful mineral or energy resources in the analyzed Yucca Mountain withdrawal area is low.

3.1.4 HYDROLOGY

This section describes the current hydrologic conditions in the Yucca Mountain region in terms of surface-water and groundwater system characteristics. The region of influence considered for surface water includes construction or land disturbance areas that could be susceptible to erosion, areas affected by permanent changes in surface-water flow, and areas downstream of the proposed repository that could be affected by eroded soil or potential spills of contaminants. The groundwater region of influence includes aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction and operations, and aquifers downgradient of the proposed repository that repository use, including long-term releases, could affect. Section 3.1.4.1 describes surface-water conditions, and Section 3.1.4.2 describes groundwater conditions.

The hydrologic system in the Yucca Mountain region is characterized and influenced by a very dry climate, limited surface water [annual average precipitation of about 10 to 25 centimeters (4 to 10 inches) (Section 3.1.2.2), potential evaporation of almost 170 centimeters (66 inches) per year (DIRS 101779-DOE 1998, Volume 1, p. 2-29)], and deep aquifers. Important characteristics of the hydrologic system include drainages and streambeds, streams, springs, and playa lakes. In addition, water quantity and quality are important characteristics. Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin of the larger Death Valley Regional Groundwater Flow System. Death Valley is a terminal hydrologic basin; surface water and groundwater cannot leave except by *evapotranspiration* (DIRS 100465-Luckey et al. 1996, p. 30). Important characteristics of the groundwater system include *recharge* zones (areas where water infiltrates from the surface and reaches the saturated zone), discharge points (locations where groundwater reaches the surface), unsaturated zones (the portion of the groundwater system above the water table), saturated zones (the portion of the groundwater system below the water table), and aquifers (water-bearing layers of rock that provide water in usable quantities). In combination, these characteristics define the quantity and quality of the available groundwater. This section also describes groundwater use as part of the system.

EVAPOTRANSPIRATION

Evapotranspiration is the loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants.

3.1.4.1 Surface Water

3.1.4.1.1 *Regional Surface Drainage*

Yucca Mountain is in the southern Great Basin, which generally lacks perennial streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas (Figure 3-11). Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry along most of their lengths most of the time. Exceptions include short stretches where groundwater discharges to or converges with the channel (DIRS 151945-CRWMS M&O 2000, p. 7.1-3); examples are near Beatty, Nevada; south of Tecopa, California; and in southern Death Valley, California. The river drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa (DIRS 103090-Bostic et al. 1997, pp. 103 and 112), and its course extends roughly 100 kilometers (60 miles) farther before it ends in the Badwater Basin in Death Valley (DIRS 151945-CRWMS M&O 2000, p. 7.1-2 and Figures 7.1-1 and 7.1-4, pp. F7.1-1 and F7.1-4), which is more than 80 meters (260 feet) below sea level (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). The nearest surface-water impoundments are Peterson Reservoir, Crystal Reservoir, Lower Crystal Marsh, and Horseshoe Reservoir.

The largest of these is Crystal Reservoir, a manmade impoundment at Ash Meadows, which captures the discharge from several springs in the area and has a capacity of 1.8 million cubic meters (1,500 acre-feet). Crystal Reservoir and other smaller pools in Ash Meadows drain to the Amargosa River through Carson Slough (DIRS 151945-CRWMS M&O 2000, p. 7.1-2).

3.1.4.1.2 *Yucca Mountain Surface Drainage*

Occurrence. No perennial streams, natural bodies of water (DIRS 151945-CRWMS M&O 2000, pp. 7.1-2 and 7.1-3), or naturally occurring wetlands (DIRS 104592-CRWMS M&O 1999, p. 2-14) occur at Yucca Mountain or in the analyzed land withdrawal area. Fortymile Wash, a major wash that flows to the Amargosa River, drains the eastern side of Yucca Mountain (Figure 3-12) (DIRS 151945-CRWMS M&O 2000, p. 7.1-2). The primary washes draining to Fortymile Wash at Yucca Mountain include Yucca Wash to the north; Drill Hole Wash, which, together with its tributary, Midway Valley Wash, drains most of the repository site; and Busted Butte (Dune) Wash to the south. The western side of Yucca Mountain

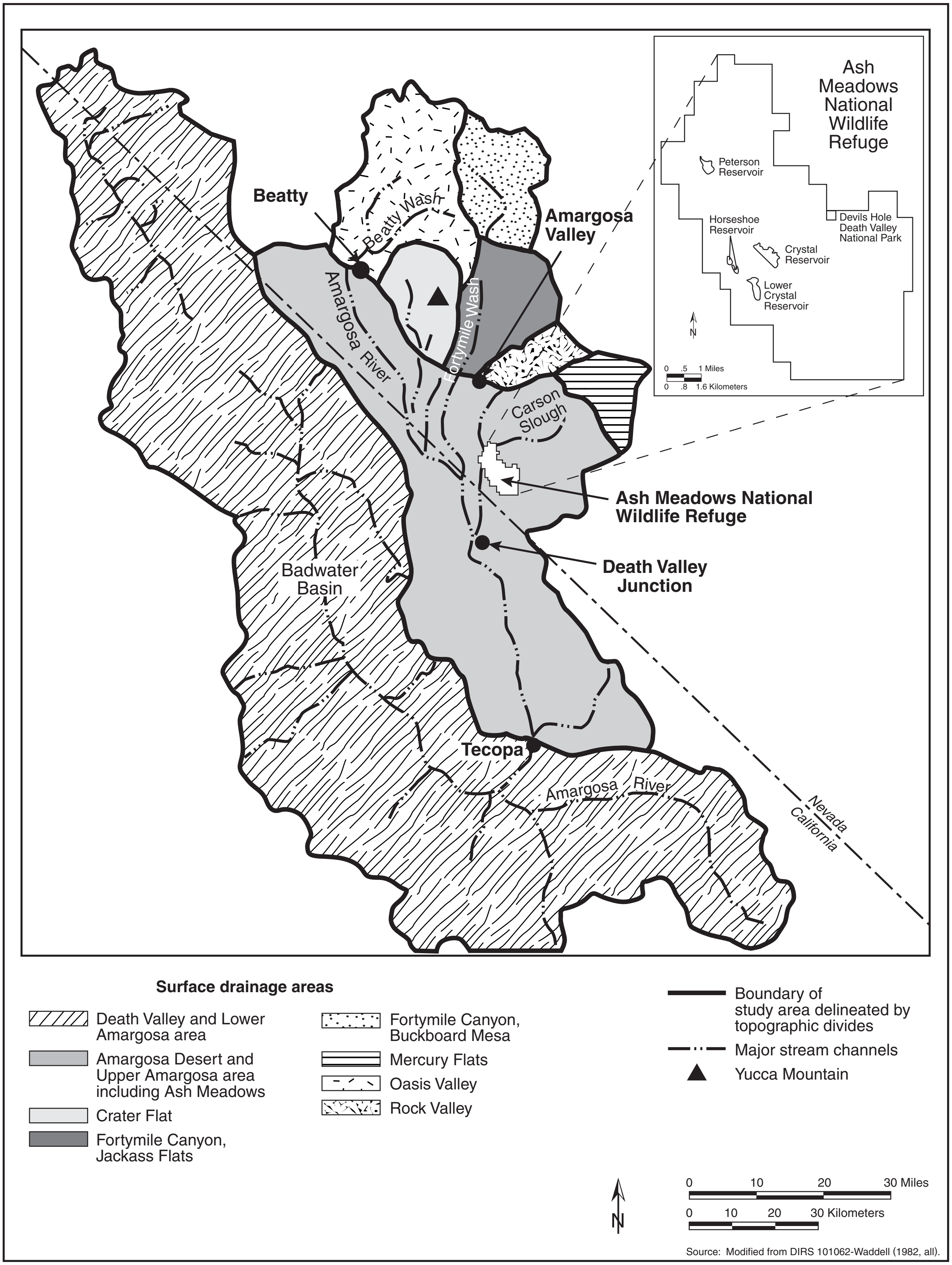

Figure 3-11. Surface areas drained by the Amargosa River and its tributaries.

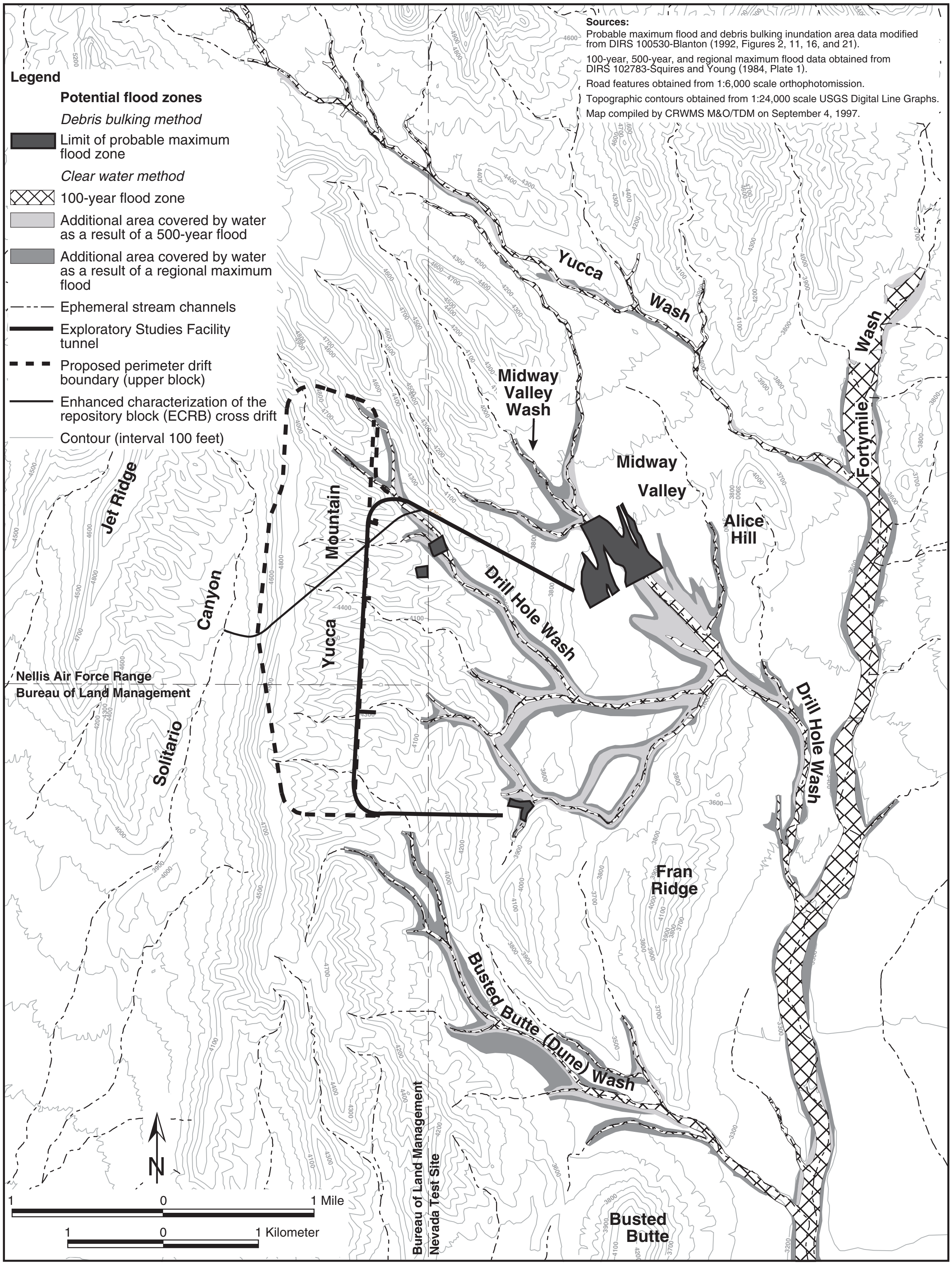

Figure 3-12. Site topography and potential flood areas.

is drained through Solitario Canyon Wash and Crater Flat, both of which eventually drain to the Amargosa River (DIRS 151945-CRWMS M&O 2000, p. 7.1-2). In this area, most of the water from summer storms is lost relatively quickly to evapotranspiration unless a storm is intense enough to produce runoff or subsequent storms occur before the water is lost (DIRS 151945-CRWMS M&O 2000, p. 7.5-1). Evapotranspiration is lower during the winter, when water from precipitation or melting snow has a better chance to result in stream flow.

Thunderstorms in the area can be local and intense, creating runoff in one wash while an adjacent wash receives little or no rain (DIRS 151945-CRWMS M&O 2000, p. 7.1-3). In rare cases, however, storm and runoff conditions can be extensive enough to result in flow being present throughout the drainage system. DIRS 155679-Glancy and Beck (1998, all) documented conditions during March 1995 and February 1998 where Fortymile Wash and the Amargosa River flow simultaneously through their primary channels to Death Valley. The 1995 event represented the first documented case of this flow condition. The 1995 event involved the higher recorded flows. The peak flow near the location where the existing Yucca Mountain access road crosses Fortymile Wash was reported as about 100 cubic meters (3,500 cubic feet) per second (DIRS 155679-Glancy and Beck 1998, p. 7). This flow is much less than that calculated as the *100-year flood* event for Fortymile Wash (as discussed in the next paragraph). The occurrence of flow throughout the drainage, however, might be a more unusual event because it would require the generation of runoff over a much larger area than the Fortymile Wash drainage, and in the same timeframe.

PREDICTED FLOODS

100-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 100 years.

500-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 500 years.

Regional maximum flood: The magnitude of a peak discharge based on data from extreme floods, in this case, occurring elsewhere in Nevada and in nearby states.

Probable maximum flood: The hypothetical peak discharge considered to be the most severe reasonably possible based on a probable maximum precipitation and other factors favorable for runoff.

Flood Potential. Although flow in most washes is rare, the area is subject to flash flooding from intense summer thunderstorms or sustained winter precipitation (DIRS 151945-CRWMS M&O 2000, p. 7.3-1). When it occurs, intense flooding can include mud and debris flows in addition to water runoff (DIRS 100530-Blanton 1992, p. 2). Table 3-9 lists peak discharges for estimated floods along the main washes at Yucca Mountain, a value for a regional maximum flood. In addition to the flood estimates listed in the table, DOE used another estimating method, the *probable maximum flood* methodology [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (DIRS 103071-ANS 1992, all)] to generate another maximum flood value for washes adjacent to the existing facilities and operations at the North and South Portals (DIRS 100530-Blanton 1992, all; DIRS 108883-Bullard 1992, all). The flood value this method generates, which includes a bulking factor to account for mud and debris (including boulder-size materials), is the most severe reasonably possible for the location under evaluation and is larger than the regional maximum flood listed in Table 3-9 (DIRS 151945-CRWMS M&O 2000, pp. 7.3-3 and 7.3-4). DOE used the probable maximum flood values to predict the areal extent of flooding and to determine if facilities and operations are at risk of flood damage.

Figure 3-12 shows the extent of estimated floods calculated for the proposed repository before the construction of the Exploratory Studies Facility. It shows the area that the estimated 100- and 500-year floods would inundate as well as the inundation area for the most conservative (highest) of the estimated maximum floods. As indicated on the figure, the partial or discontinuous inundation areas in Midway Valley Wash and the upper reaches of Drill Hole Wash are based on the probable maximum flood values derived in accordance with guidelines of the American National Standards Institute and American Nuclear Society; for other areas, the most extensive flood zones are based on the regional maximum flood levels listed in Table 3-9. The figure also shows that all floods along Fortymile Wash and Yucca Wash would remain within existing stream channels.

Table 3-9. Estimated peak discharges along washes at Yucca Mountain.[a]

Name	Drainage area (square kilometers)[b]	Peak discharge 100-year flood (cubic meters per second)[c]	Peak discharge 500-year flood (cubic meters per second)	Regional maximum flood (cubic meters per second)
Fortymile Wash	810	340	1,600	15,000
Busted Butte (Dune) Wash	17	40	180	1,200
Drill Hole Wash[d]	40	65	280	2,400
Yucca Wash	43	68	310	2,600

a. Source: DIRS 102783-Squires and Young (1984, p. 2).
b. To convert square kilometers to square miles, multiply by 0.3861.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. Includes Midway Valley and South Portal Washes as tributaries—North and South Portal Areas.

Along Busted Butte (Dune) and Drill Hole Washes, the *500-year flood* would exceed stream channels at several places, and the probable maximum flood would inundate broad areas in Midway Valley Wash near the North Portal. None of the identified flood estimates predicts water levels high enough to reach either the North or South Portal opening to the subsurface facilities (DIRS 100530-Blanton 1992, pp. 4 and 7), which would be at either end of the Exploratory Studies Facility tunnel shown in the figure.

The U.S. Geological Survey (DIRS 103469-Thomas, Hjalmarson, and Waltemeyer 1997, all) recently published a revised methodology for calculating peak flood discharges in the southwestern United States. A preliminary evaluation indicates that the methodology, if appropriate for use, could result in estimates for 100-year floods that are larger than those listed in Table 3-8 and shown in Figure 3-12. However, the new methodology affects only the 100-year flood estimate, so discharge numbers and expanded inundation lines resulting from its use would be within the bounds set by the 500-year flood.

DOE has prepared a *floodplain* assessment for the Proposed Action in accordance with the requirements of 10 CFR Part 1022. Appendix L contains the floodplain assessment.

Surface-Water Quality. Samples of stream waters in the Yucca Mountain region have been collected and analyzed for their general chemical characteristics. Because surface-water flows are rare and in immediate response to storms, data from sampling events are sparse. Results of the surface-water sample analyses (Table 3-10) bear some resemblance to those from groundwater samples, as discussed in Section 3.1.4.2.2, because both contain bicarbonate as a principal component. However, in general, the groundwaters have a higher mineral content, suggesting more interaction between rock and water (see Section 3.1.4.2.2, Tables 3-13 and 3-17).

3.1.4.2 Groundwater

This section discusses groundwater, first on a regional basis and then in the Yucca Mountain vicinity. Many studies have been conducted on the groundwater system under and surrounding Yucca Mountain. These studies provide a firm basis of understanding of the hydrology of the region. However, because

Table 3-10. Chemistry of surface water in the Yucca Mountain region.[a]

Chemical[b]	Range of chemical composition
pH	7.8 - 8.4
Total dissolved solids (milligrams per liter)	45.0 - 123
Calcium (milligrams per liter)	6.7 - 28.0
Magnesium (milligrams per liter)	0.7 - 3.9
Potassium (milligrams per liter)	3.2 - 11.0
Sodium (milligrams per liter)	2.4 - 16.0
Bicarbonate (milligrams per liter)	32.0 - 109
Chloride (milligrams per liter)	1.3 - 10.0
Sulfate (milligrams per liter)	4.1 - 24.0
Silica (milligrams per liter)	4.5 - 36.0

a. Source: DIRS 151945-CRWMS M&O (2000, Table 5.3-3, p. T5.3-7).
b. Based on 18 samples from 15 different surface-water locations (12 involve a single sampling event and 3 involve two sampling events) collected from 1984 to 1995. One milligram per liter is equivalent to one part per million.

groundwater systems are complex and difficult to study, there are differences of opinion among experts related to interpreting available data and describing certain aspects of the Yucca Mountain groundwater system. Therefore, this section also discusses the various views on the groundwater system under Yucca Mountain, where viewpoints differ.

3.1.4.2.1 *Regional Groundwater*

The groundwater flow system of the Death Valley region is very complex, involving many *aquifers* and confining units. Over distance, these layers vary in their characteristics or even their presence (DIRS 151945-CRWMS M&O 2000, pp. 9.2-5 to 9.2-10). In some areas confining units allow considerable movement between aquifers; in other areas confining units are sufficiently impermeable to support artesian conditions (where water in a lower aquifer is under pressure in relation to an overlying confining unit; when intersected by a well, the water will rise up the borehole).

In general, the principal water-bearing units of the Death Valley regional groundwater flow system (or simply Death Valley region) are grouped in three types of saturated hydrogeologic units: basin-fill alluvium (or alluvial aquifer), volcanic aquifers, and carbonate aquifers (DIRS 151945-CRWMS M&O 2000, pp. 9.2-23 and 9.2-24). An alluvial aquifer is in a *permeable* body of sand, silt, gravel, or other detrital material deposited primarily by running water. Volcanic and carbonate aquifers are in permeable units of *igneous* (of volcanic origin) and carbonate (limestone or dolomite) rock, respectively. The mountainous area that makes up the north-central portion of the Death Valley region that includes the Yucca Mountain area is often underlain by volcanic rocks and associated volcanic aquifers. The valley or basin areas to the south and southeast of Yucca Mountain contain alluvial aquifers, including those beneath the Amargosa Desert. Carbonate aquifers are regionally extensive and generally occur at large depths below volcanic aquifers or alluvial aquifers (DIRS 151945-CRWMS M&O 2000, p. 9.6-2). The discussion of groundwater at Yucca Mountain describes the position of the various aquifers and confining units in relation to each other and to stratigraphic units.

The alluvial aquifers below the Amargosa Desert receive underflow (groundwater movement from one area to another) from groundwater basins to the north as well as from basin areas to the east and, therefore, contain a mixture of water from several different aquifers (DIRS 151945-CRWMS M&O 2000, pp. 9.2-16 to 9.2-18). For example, the volcanic aquifers beneath Yucca Mountain are believed to provide inflow to the alluvial aquifers beneath the Amargosa Desert. In addition, the springs in the Ash Meadows area are fed in part by the carbonate aquifers (DIRS 101167-Winograd and Thordarson 1975, p. C53) and what is not discharged through the springs flows into groundwater moving through the alluvial aquifers at the southeast end of the Amargosa Desert and then discharges at Alkali Flat (Franklin Lake Playa) or continues as groundwater into Death Valley (DIRS 151945-CRWMS M&O 2000, pp. 9.2-17 and 9.2-18). There is also evidence that indicates a carbonate aquifer might be present below the volcanic sequence, extending from eastern Yucca Mountain south into the Amargosa Desert (DIRS 100465-Luckey et al. 1996, pp. 32 and 40).

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HYDROGEOLOGIC TERMS

Permeability: Describes the ease or difficulty with which water passes through a given material. Permeable materials allow fluids to pass through readily, while less permeable materials inhibit the flow of fluids.

Aquifer: A permeable water-bearing unit of rock or sediment that yields water in a usable quantity to a well or spring.

Saturated zone: The area below the water table where all spaces (fractures and rock pores) are completely filled with water.

Confining unit (or aquitard): A rock or sediment unit of relatively low permeability that retards the movement of water in or out of adjacent aquifers.

Inflow: Sources of water flow into a groundwater system such as surface infiltration (recharge) or contributions from other aquifers.

Basins. The Death Valley regional groundwater flow system (Figure 3-13) or region covers about 50,000 square kilometers (19,000 square miles) (DIRS 151945-CRWMS M&O 2000, p. 9.2-3). Straddling the Nevada-California border, this flow system includes several prominent valleys (Amargosa Desert, Pahrump Valley, and Death Valley) and their separating mountain ranges and extends north to the Kawich Valley, encompassing all of the Nevada Test Site (DIRS 151945-CRWMS M&O 2000, Figures 9.2-1 and 9.2-2, pp. F9.2-1 and F9.2-2). The major recharge areas are mountains in the east and north portions of the region (DIRS 151945-CRWMS M&O 2000, pp. 9.2-11 and 9.2-15). The discharge points are primarily to the south and include the southernmost discharge points in Death Valley and intermediate points such as Ash Meadows in the Amargosa Desert and Alkali Flat (DIRS 151945-CRWMS M&O 2000, p. 9.2-13). Therefore, flow is primarily to the west or south. Figure 3-13 shows a slightly reduced outline for the regional flow system that some Yucca Mountain Site Characterization Project modeling efforts (for example, DIRS 100131-D'Agnese et al. 1997, all) have used as the boundary. This reduced area is divided into the Northern, Central, and Southern Death Valley subregions. The Central Death Valley subregion contains the area of Yucca Mountain.

Hydrologic investigations of the Death Valley region date back to the early 1900s, with early work performed primarily by the U.S. Geological Survey (DIRS 100131-D'Agnese et al. 1997, p. 4). More recently, studies by both the U.S. Geological Survey and the State of Nevada have included efforts to collect and compile water-level data from regional wells (DIRS 151945-CRWMS M&O 2000, p. 9.2-39). DOE has collected groundwater-level data from wells at Yucca Mountain and in neighboring areas on a routine basis since 1983, and has used the levels to which water rises in these wells—called the *potentiometric surface*—to map the slope of the groundwater surface and to determine the direction of flow. Figure 3-14 is a potentiometric surface map of the Death Valley regional groundwater flow system. Based on these and other data, groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley (Figure 3-15). The area around Yucca Mountain is in the central subregion of the Death Valley region, and this subregion has three groundwater basins: (1) Ash Meadows, (2) Alkali Flat-Furnace Creek, and (3) Pahute Mesa-Oasis Valley (DIRS 102893-Rush 1971, pp. 10 and 11; DIRS 101062-Waddell 1982, pp. 13 to 20; DIRS 100465-Luckey et al. 1996, pp. 28-30; and DIRS 100131-D'Agnese et al. 1997, p. 65). The aquifers below Yucca Mountain have been included in the Alkali Flat-Furnace Creek groundwater basin because of evidence that the groundwater discharges mainly at Alkali Flat (Franklin Lake Playa) and potentially to the Furnace Creek Wash area of Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18).

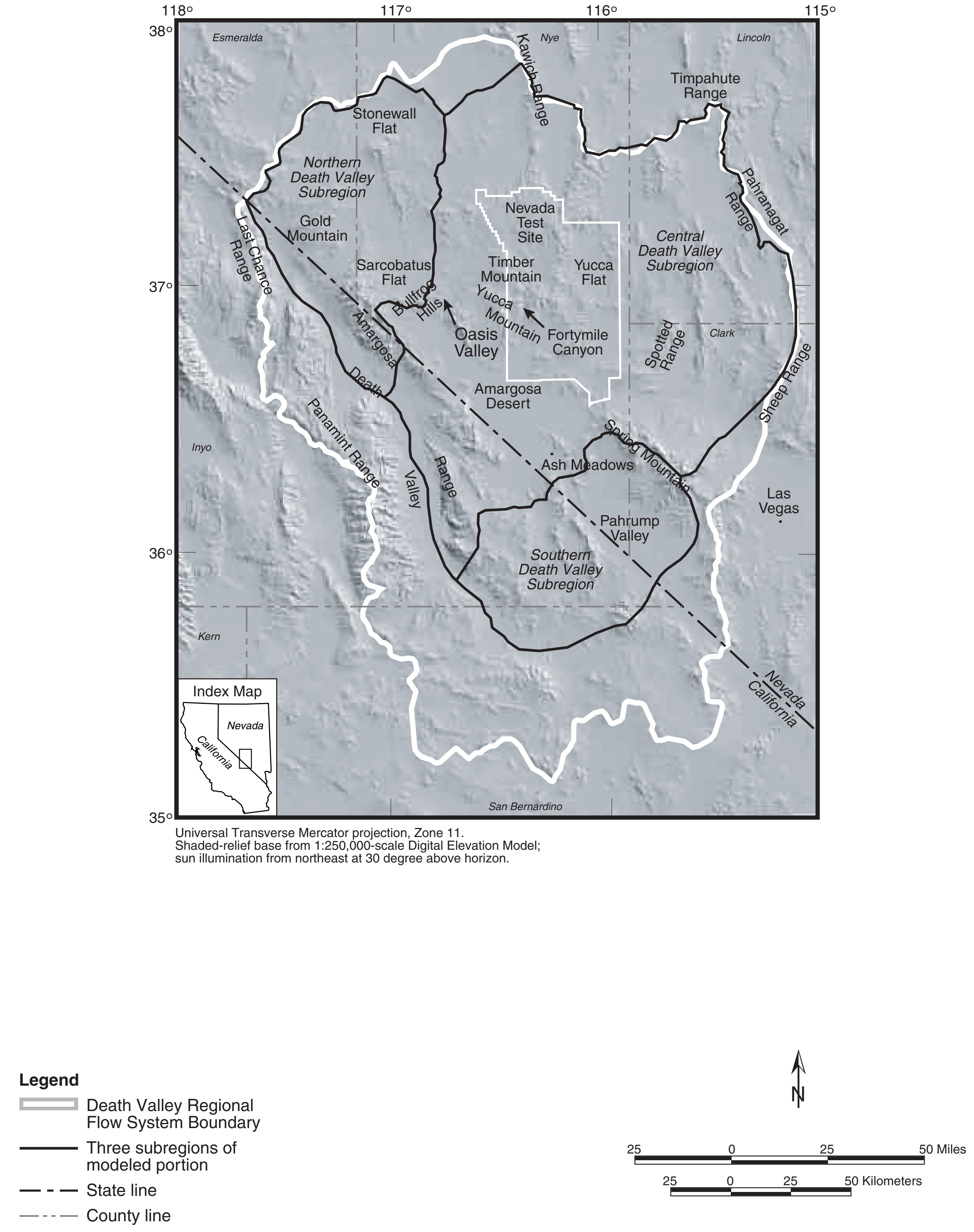

Figure 3-13. Boundaries of Death Valley regional groundwater flow system.

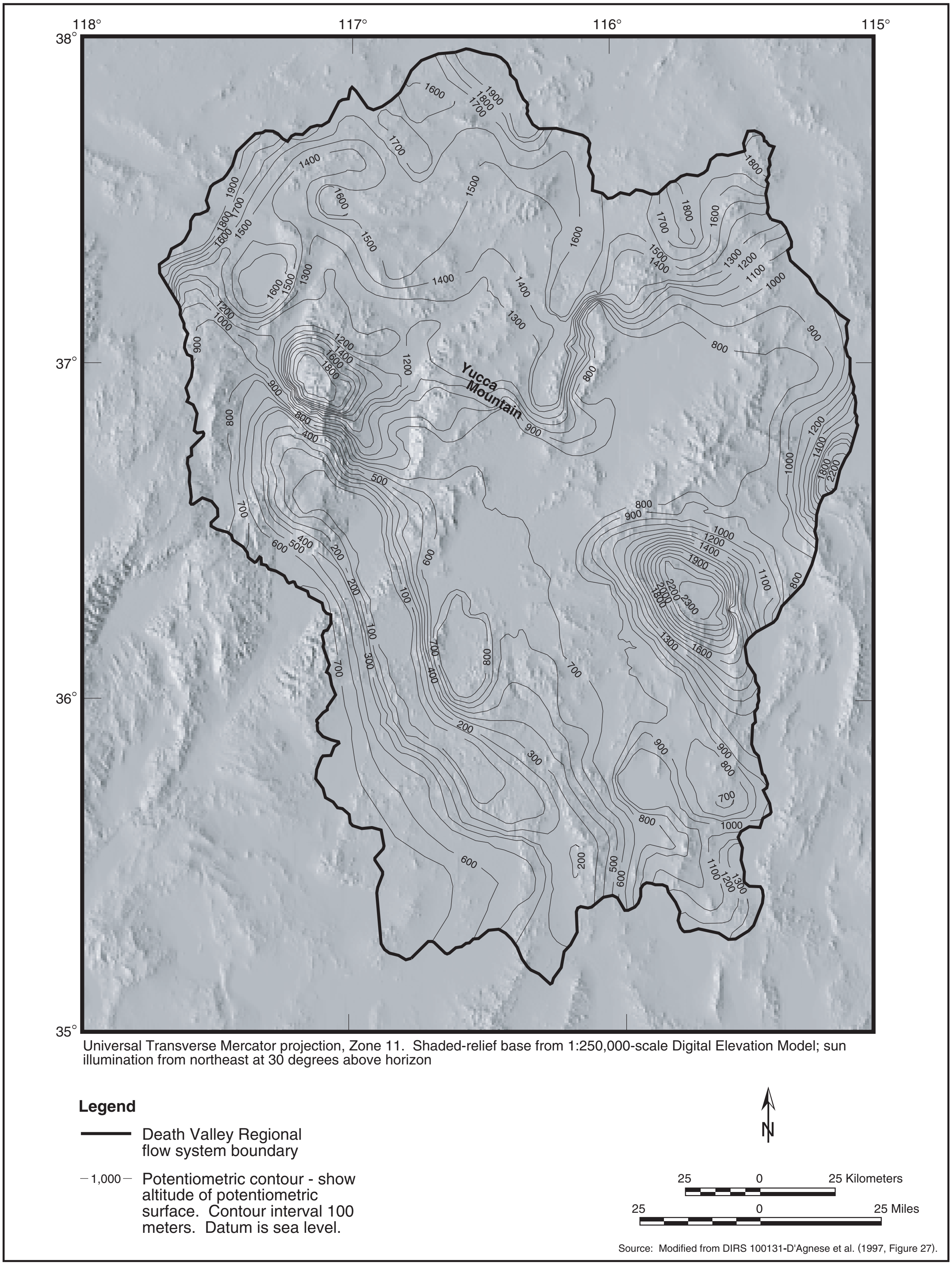

Figure 3-14. Estimated potentiometric surface of the Death Valley region.

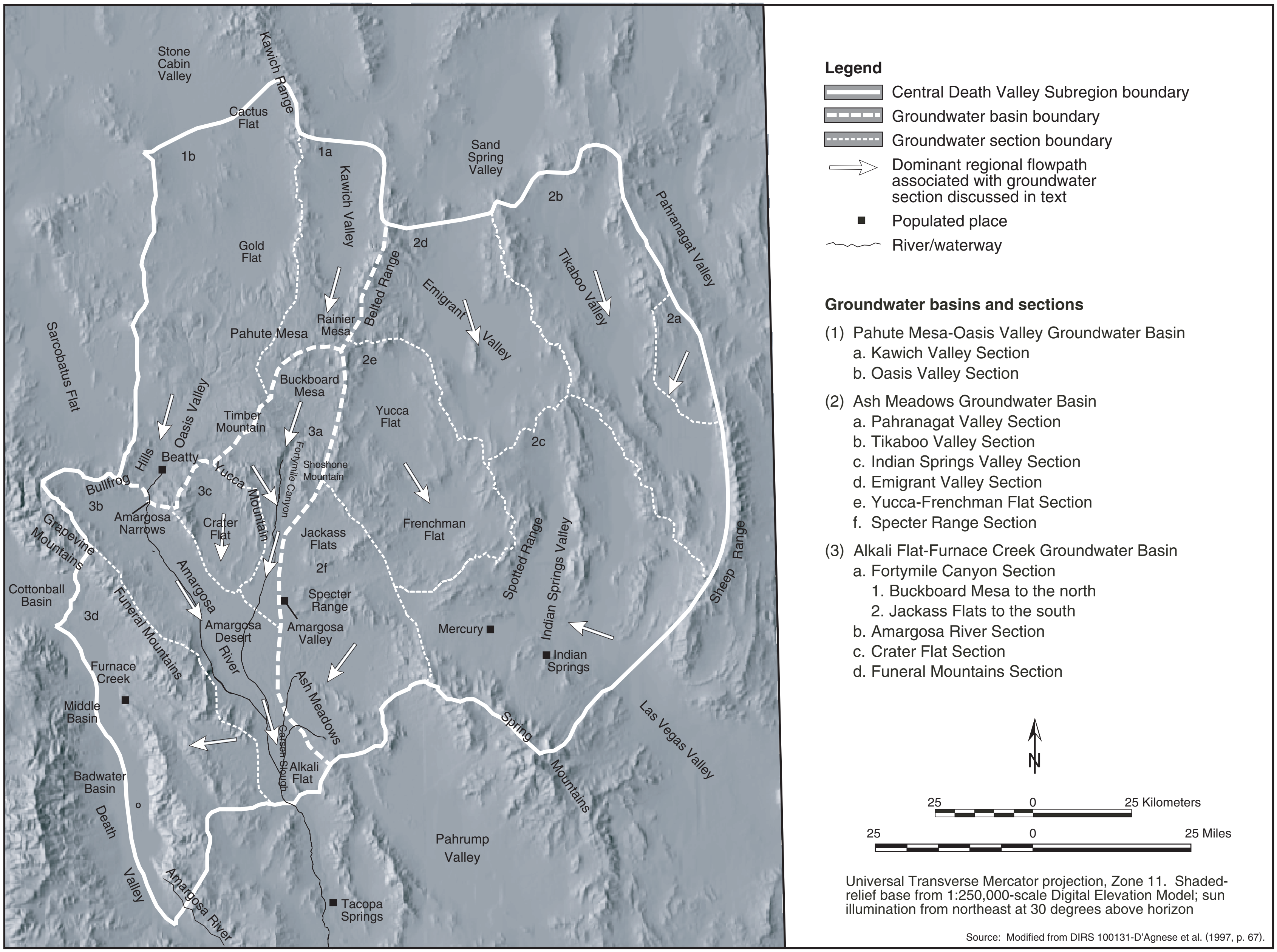

Figure 3-15. Groundwater basins and sections of the Central Death Valley subregion.

The Ash Meadows groundwater basin is the easternmost of the three basins that make up the Central Death Valley subregion. It underlies eastern portions of the Nevada Test Site (Yucca Flat, Frenchman Flat, Mercury Valley, Rock Valley), parts of Shoshone Mountain, Rainier Mesa to the north, and the Ash Meadows area of the Amargosa Desert in the south. Inflow is principally from the Spring Mountains, Pahranagat Range, Sheep Range, and Pahranagat Valley in the eastern portion of the basin (DIRS 100131-D'Agnese et al. 1997, pp. 67 and 68). Outflow is basically in the form of discharge to the surface and underflow to the lower portion of the Alkali Flat-Furnace Creek groundwater basin. The primary discharge point for this groundwater basin is Ash Meadows, where springs occur in a line along a major fault (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). Estimates of discharge at Ash Meadows range from 21 million to 37 million cubic meters (17,000 to 30,000 acre-feet) per year (DIRS 103022-Walker and Eakin 1963, p. 24; DIRS 100131-D'Agnese et al. 1997, p. 46).

The Pahute Mesa-Oasis Valley groundwater basin includes Oasis Valley, Gold Flat, the southern parts of Cactus Flat and Kawich Valley, and the western portion of Pahute Mesa. Recharge areas are primarily in the north in the Belted and Kawich Ranges and Pahute Mesa, but include Timber Mountain and the Bullfrog Hills, and along the Amargosa River and its tributaries (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). Subsurface outflow is into the Amargosa Desert of the Alkali Flat-Furnace Creek groundwater basin, and has been estimated at about 0.49 million cubic meters (400 acre-feet) per year (DIRS 106695-Malmberg and Eakin 1962, p. 26).

The Alkali Flat-Furnace Creek groundwater basin is bordered on the northwest by the Pahute Mesa-Oasis Valley basin and on the east by the Ash Meadows basin. This groundwater basin includes portions of the Nevada Test Site (parts of Rainier Mesa, Pahute Mesa, and Buckboard Mesa to the north, Shoshone Mountain, Yucca Mountain, and Jackass Flats in the southern half), Crater Flat in the west, and part of Death Valley and the central part of the Amargosa Desert in the south (DIRS 100131-D'Agnese et al. 1997, pp. 67 to 69). As shown in Figure 3-15, this basin includes the groundwater area designated as the Fortymile Canyon Section, which includes the area of Buckboard Mesa to the north and a portion of Jackass Flats to the south. Groundwater moving beneath the proposed repository site is in the Fortymile Canyon section.

In the immediate vicinity of Yucca Mountain, sources of recharge to the groundwater include Fortymile Wash and precipitation that infiltrates the surface. However, these local sources are not among the primary sources of recharge in the area that makes up the Alkali Flat-Furnace Creek groundwater basin. The primary sources of surface recharge in this area are infiltration on Pahute Mesa, Rainier Mesa, Timber Mountain, and Shoshone Mountain to the north (DIRS 151945-CRWMS M&O 2000, p. 9.2-18), and the Grapevine and Funeral Mountains to the south (DIRS 100131-D'Agnese et al. 1997, p. 68). One numerical model of infiltration for Yucca Mountain used energy- and water-balance calculations to obtain an average infiltration rate of 4.7 millimeters (0.2 inch) a year over the potential repository area for the current climate (DIRS 151945-CRWMS M&O 2000, Table 8.2-9, p. T8.2-7). This represents less than 3 percent of an average annual precipitation rate of about 200 millimeters (8 inches) used in the model for the crest at Yucca Mountain. In comparison, areas such as Pahute Mesa, Timber Mountain, and Shoshone Mountain receive more precipitation (DIRS 103021-DOE 1997, Plate 1) and have higher estimated percentages of precipitation infiltrating deep into the ground and eventually becoming recharge to the aquifer.

Water infiltrating at Yucca Mountain and becoming recharge to the groundwater would join with water in the Fortymile Canyon Section (Figure 3-15). From there the general direction of groundwater flow is to the Amargosa Desert basin and then Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18). There have been many estimates of the amount of groundwater moving along this path. One study (DIRS 103016-State of Nevada 1971, p. 50) that is still used extensively by the State of Nevada in its groundwater planning efforts estimated annual groundwater movement of 10 million cubic meters (8,100 acre-feet) from the area of Jackass Flats to the Amargosa Desert and 23.4 million cubic meters

(19,000 acre-feet) from the Amargosa Desert to Death Valley. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres) (the largest repository footprint under any of the operating modes), assuming 4.7 millimeters (0.2 inch) of infiltration per year, would be about 0.2 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

DOE has performed a study (DIRS 157072-BSC 2001, all) to develop an "expected-case" model of groundwater flow in the saturated zone from beneath Yucca Mountain. The primary objective of the study was to evaluate the effects of several specific elements of conservatism in the groundwater flow model used in the Total System Performance Assessment (TSPA; see Chapter 5 and Appendix I). The study looked at the physical parameter values used in that model, for example the diffusion coefficient, porosity for fractured tuffs, and *permeability* for alluvial materials. It also looked at the location assumed in the TSPA where the groundwater flow path in the saturated zone changes from tuff to alluvial material. The recent effort looked at data collected on several specific parameters that would support what were felt to be more realistic, less conservative values. The expected-case model was run with these parameters changed and assuming a nonsorbing tracer was released as a point source to the water table beneath the proposed repository. The results of these model runs indicated it would take in the range of 1,000 to 1,500 years for 50 percent of the tracer to reach a distance of 20 kilometers (12 miles) in the groundwater flow path (DIRS 157072-BSC 2001, Figure 10, p. 43). Some of the tracer would find its way to faster pathways; some would take longer to travel the distance. DOE believes these estimates of groundwater travel time in the saturated zone represent reasonable estimates of what occurs in the natural setting.

As water in the Alkali Flat-Furnace Creek groundwater basin moves south through the Amargosa Desert, eastern portions of the flow are joined by underflow from the Ash Meadows groundwater basin (DIRS 101779-DOE 1998, Volume 1, pp. 2-56 to 2-58). The line of springs formed by discharge from the Ash Meadows groundwater basin provides much of the boundary between the two basins (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). In this area there is a marked decline of about 64 meters (210 feet) in water table elevation between Devils Hole and Carson Slough, approximately 6.4 kilometers (4 miles) to the west (DIRS 103415-Dudley and Larson 1976, p. 23). This elevation decline indicates that the potential groundwater flow is from Ash Meadows toward the Alkali Flat-Furnace Creek groundwater basin, rather than the opposite. The primary groundwater discharge point for this groundwater basin is Alkali Flat (Franklin Lake Playa) as indicated by the potentiometric surface (or slope) of the groundwater and hydrochemical data. A small portion could move toward discharge points in the Furnace Creek area of Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18).

Different researchers have speculated that the general flow boundaries of the three groundwater basins in the Central Death Valley subregion are in slightly different locations (DIRS 100131-D'Agnese et al. 1997, p. 59). Some studies [for example, DIRS 101062-Waddell (1982, p. 15)] have placed the Kawich Valley area in the Alkali Flat-Furnace Creek groundwater basin rather than in the Pahute Mesa-Oasis Valley groundwater basin as shown in Figure 3-15. This uncertainty in general flow boundaries is a reflection of the complex groundwater flow systems in the Death Valley region. The differing interpretations of the groundwater basin boundaries do not, however, disagree on the relative location of the aquifers below Yucca Mountain, which are consistently placed in the central Alkali Flat-Furnace Creek basin.

To reduce uncertainties, studies of the regional groundwater flow system are continuing. This is particularly true of that portion of the flow system that is downgradient of Yucca Mountain. Nye County, under a Cooperative Agreement with DOE, has implemented the Early Warning Drilling Program to install a series of wells in the Amargosa Valley area and the southern part of the Nevada Test Site. The purpose of this program is to characterize and monitor the saturated zone along possible transport pathways from Yucca Mountain. At the time this document was prepared, plans were underway to extend this program, which was originally set at 3 years (with a scheduled end date of November 2001). Under terms of the agreement, Nye County has had the responsibility to drill, test, and monitor a series of shallow and deep wells to investigate the upper volcanic or alluvial aquifers and the deep carbonate aquifer. The objective of the work is to determine aquifer characteristics, water chemistries, and flow paths. The County provides DOE splits of all samples collected and copies of all data obtained. DOE will continue to study the saturated zone south of Yucca Mountain through the simultaneous collection of data from this program and the use of data obtained by Nye County. In addition, a set of wells will be installed in Fortymile Wash to help identify the extent of the alluvium and valley fill along the potential flow path. Some of these wells will also be used to support an Alluvial Testing Complex, where aquifer and tracer tests in the alluvium and valley fill will be conducted. DIRS 156115-NWRPO (2001, all) described its efforts for Fiscal Years 1996 to 2001 in an August 2001 report prepared for DOE. Some of the groundwater findings discussed in this report include the following:

- Valley-fill deposits in the Amargosa Desert Area are very complex. Subsurface investigations have shown evidence of groundwater compartments as a result of faulting in the underlying rock. The conceptual hydrogeological model being developed from this information suggests that these compartments and boundaries between compartments serve either as groundwater flow pathways or as barriers. However, with several exceptions, the number and locations of compartments have not yet been well defined.

- Water level monitoring and temperature logs in wells suggest an upward gradient from underlying carbonate basement rocks into overlying valley-fill sediments.

- Evidence of transient (that is, varying over time) flow conditions in the past 50 years suggests it might be appropriate to calibrate groundwater flow models to transient flow conditions rather than the assumed steady-state conditions.

Although the Nye County report discusses these and other findings, Nye County and DOE have shared test results and data throughout the program. DOE has used and will continue to use the data collected from the Nye County and alluvial testing programs to refine its understanding of flow and transport mechanics south of Yucca Mountain. The information gained from these and other studies will be used to evaluate the accuracy and adequacy of similar information used in assessing the long-term performance of the proposed repository. The new information will also be used, as appropriate, in future iterations of conceptual and numerical models supporting the long-term performance assessment (see Chapter 5).

Use. Table 3-11 summarizes groundwater use in the Yucca Mountain region. The *hydrographic areas* listed in the table are basically a finer division of the subregions and groundwater basins discussed above; their locations are roughly consistent with the sectional divisions shown in Figure 3-15. These locations do not precisely match the groundwater area designations described in the preceding discussion because hydrographic areas generally reflect topographic divides (such as mountain ranges and valleys) that in some cases do not correspond to divides based on groundwater movement. The hydrographic area designations are important because the State of Nevada uses them as the basic units in its water planning and appropriations efforts.

DOE has been using small amounts of Jackass Flats hydrographic area groundwater for Nevada Test Site operations, and Yucca Mountain activities have contributed to water use from this source. Most water use in the Alkali Flat-Furnace Creek groundwater basin, however, occurs south of Yucca Mountain, from the Amargosa Desert alluvial aquifer (DIRS 151945-CRWMS M&O 2000, p. 9.2-23). Between 1985 and 1992, water use in the Amargosa Desert from this aquifer averaged 8.1 million cubic meters (6,600 acre-feet) a year for agriculture, mining, livestock, and domestic purposes (DIRS 147766-Thiel 1999, p. 15).

Table 3-11. Perennial yield and water use in the Yucca Mountain region.

Hydrographic area[a]	Perennial yield[b,c] (acre-feet per year)[d]	Current appropriations[e,c] (acre-feet per year)	Average annual withdrawals 1995-1997 (acre-feet)	Chief uses
Jackass Flats (Area 227a)	880[f] - 4,000	500[g]	340[h]	Nevada Test Site programs and site characterization of Yucca Mountain. Minor amounts of water are also discharged for tests at Yucca Mountain.
Crater Flat (Area 229)	220 - 1,000	1,200[i]	140[j]	Mining, site characterization of Yucca Mountain
Amargosa Desert (Area 230)	24,000 - 34,000	27,000	14,000[j]	Agriculture, mining, livestock, municipal, wildlife habitat
Oasis Valley (Area 228)	1,000 - 2,000	1,700	N/A[k]	Agriculture, municipal

a. A specific area in which the State of Nevada allocates and manages the groundwater resources. See Figure 3-20.
b. The quantity of groundwater that can be withdrawn annually from a groundwater reservoir, or basin, for an indefinite period of time without depleting the reservoir; also referred to as *safe yield*.
c. Sources: DIRS 147766-Thiel (1999, p. 5-12); perennial yield values only, DIRS 101811-DOE (1996, pp. 4-117 and 4-118).
d. An *acre-foot* is a commonly used hydrologic measurement of water volume equal to the amount of water that would cover an acre of ground to a depth of 1 foot. To convert acre-feet to cubic meters, multiply by 1,233.49; to convert to gallons, multiply acre-feet by 325,851.
e. The amount of water that the State of Nevada authorizes for use; the amount used might be much less. These appropriations do not cover Federal Reserve Water Rights held by the Nevada Test Site or Air Force.
f. The low estimate for perennial yield from Jackass Flats breaks the quantity down further into 300 acre-feet for the eastern third of the area and 580 acre-feet for the western two-thirds.
g. Area 227a appropriations include about 370 acre-feet for Yucca Mountain characterization activities.
h. Source of Area 227a withdrawals: DIRS 101486-Bauer et al. (1996, p. 702) and DIRS 103090-Bostic et al. (1997, p. 592) for withdrawals from wells J-12 and J-13 at the Nevada Test Site.
i. Area 229 appropriations include temporary mining rights and 61 acre-feet for Yucca Mountain characterization activities.
j. Sources of Area 229 and 230 withdrawals: DIRS 102890-La Camera, Westenburg, and Locke (1996, p. 74) and DIRS 103011-La Camera and Locke (1997, p. 77).
k. N/A = not available.

As Table 3-11 indicates, water use averaged about 17 million cubic meters (14,000 acre-feet) a year from 1995 through 1997. As listed in Table 3-11, groundwater in the Amargosa Desert is heavily appropriated—at much higher levels than is actually withdrawn.

The Ash Meadows area of the Amargosa Desert has restrictions on groundwater withdrawal as a result of a U.S. Supreme Court decision (DIRS 148102-Cappaert v. United States 1976, all) to protect the water level in Devils Hole. Devils Hole became a National Monument in 1952 to preserve the Devils Hole pupfish and the pool in which the fish live. The pool contains a rock shelf that is critical to the survival of the Devils Hole pupfish because it provides an area for the fish to feed and spawn. Withdrawal of water from the connected aquifer has caused the water level in the pool to decline. The Supreme Court found that an existing Federal water right precluded development of the aquifer to the extent that the water level in the pool be maintained at a level providing adequate coverage of the rock shelf and, thereby, providing the necessary habitat for the pupfish. The Ash Meadows National Wildlife Refuge (see Figure 3-11), which includes the Devils Hole area, was established in 1984 (see Section 3.1.5.1.3). As noted above in the discussions of basins and regional groundwater movement, groundwater flowing beneath Yucca Mountain does not contribute to the groundwater beneath the area of Ash Meadows. However, the slope of the water table from Ash Meadows to the Amargosa Desert could be affected by changes in the Desert's water table elevation.

Table 3-11 lists water volumes (*perennial yield*, appropriations, and withdrawals) in acre-feet. This unit of volume is common in hydrology and water resource planning. This EIS describes water volumes in both metric (cubic meters) and English (acre-feet) units.

Groundwater Quality. The U.S. Geological Survey has accumulated and evaluated almost 90 years of groundwater data for the Yucca Mountain region and, in more recent years, has periodically collected and analyzed groundwater quality samples (DIRS 104986-CRWMS M&O 1999, pp. 6 to 9). A recent sampling effort (DIRS 104828-Covay 1997, all) looked for a wide range of inorganic and organic constituents, as well as general water quality properties. This effort collected samples from five groundwater sources in the Amargosa Desert region and three from the immediate vicinity of Yucca Mountain (as discussed in Section 3.1.4.2.2). The regional sampling locations included two wells in the central Amargosa Desert, one well in the Ash Meadows area, and two springs along the border between the Alkali Flat-Furnace Creek and Ash Meadows groundwater basins. Selected results from the recent groundwater sampling effort are listed in Table 3-12.

Table 3-12. Concentrations of selected water quality parameters in the regional groundwater.[a,b,c]

Parameter	Range of reported concentrations (milligrams per liter)	Parameter	Range of reported concentrations (milligrams per liter)
Aluminum	0.0021 - 0.0049	Lead	<0.001 - 0.0013
Antimony	<0.001 (all)	Manganese	<0.001 - 0.0022
Arsenic	0.008 - 0.022	Mercury	<0.0001 (all)
Barium	0.0012 - 0.067	Molybdenum	0.0027 - 0.010
Beryllium	<0.001 (all)	Nickel	<0.001 (all)
Boron	0.114 - 1.06	Nitrite	<0.010 (all)
Cadmium	<0.001 (all)	Nitrite plus nitrate	<0.050 - 2.17
Chloride	6.6 - 100	Selenium	<0.001 - 0.019
Chromium	0.0022 - 0.0065	Silver	<0.001 (all)
Copper	<0.001 - 0.001	Strontium	0.041 - 1.53
Cyanide	<0.01 (all)	Sulfate	18 - 420
Fluoride	1.6 - 2.3	Thallium	<0.0005 (all)
Iron	<0.003 - 0.014	Total dissolved solids (TDS)	217 - 1,110
Organochlorine and organonitrogen compounds (analysis for 45 constituents)	None detected[d] (0.00001 - 0.001)	Zinc	<0.001 - 0.027
Volatile organic compounds (analysis for 60 constituents)	None detected[d] (0.001 - 0.006)	Semivolatile organic compounds (analysis for 57 constituents)	None detected[d] (0.003 - 0.040)

a. Source: DIRS 104828-Covay (1997, all).
b. Samples collected in May 1997 from eight locations (five in the Amargosa Desert region and three in the vicinity of Yucca Mountain).
c. Parameters selected for display are primarily those identified in EPA's Primary and Secondary Drinking Water Standards.
d. "None detected" indicates no results were above the analytical laboratory's detection limits. The range of reported detection limits is in parentheses.

The U.S. Geological Survey effort compared the regional groundwater quality measurements to the primary and secondary drinking water standards established by the Environmental Protection Agency [DIRS 104876-EPA 1993, all; see also the Safe Drinking Water Act, as amended, 42 U.S.C. 300(f) *et seq.*]. Though drinking water standards are for public water supply systems, it is common to compare results from groundwater sampling and analysis to these standards for an indication of groundwater quality. The findings indicated that the five groundwater sources met primary drinking water standards, but that a few sources exceeded secondary and proposed standards. Specifically, four of the wells exceeded a proposed standard for radon (Section 3.1.8.2 discusses the natural occurrence of radon in the Yucca Mountain region) and one of those four exceeded secondary standards for sulfate and total dissolved solids and a proposed standard for uranium. Overall, however, regional groundwater quality is generally good and consistent with the State of Nevada description that most groundwater aquifers in the State are suitable, or marginally suitable, for most uses (DIRS 148164-NDWP 1999, all). Additional water quality data for wells on the Nevada Test Site are available in the *Final Environmental Impact*

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Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada (DIRS 101811-DOE 1996, pp. 4-124 to 4-126). Section 3.1.4.2.2 discusses radiological parameters, including results from regional sample locations.

3.1.4.2.2 *Groundwater at Yucca Mountain*

Groundwater at Yucca Mountain occurs in an unsaturated zone and a saturated zone. This section describes these zones and the characteristics of the groundwater in them.

> **SUBSURFACE FORMATIONS CONTAINING WATER**
>
> **Unsaturated zone:** The zone of soil or rock between the land surface and the *water table*.
>
> **Saturated zone:** The region below the *water table* where rock pores and *fractures* are completely saturated with *groundwater*.
>
> **Perched water bodies:** Saturated lenses (thin layers of water) surrounded by unsaturated conditions.

Unsaturated Zone

Water Occurrence. The unsaturated zone at Yucca Mountain extends down from the crest of the mountain about 750 meters (2,500 feet) to the water table (the upper surface of the saturated zone) (DIRS 151945-CRWMS M&O 2000, p. 8.1-1). The primary emplacement area (the upper block) of the proposed repository would be in the unsaturated zone, at least 160 and up to 400 meters (530 up to 1,300 feet) above the present water table (DIRS 151945-CRWMS M&O 2000, p. 9.4-1). The excavation of the Exploratory Studies Facility, including the Enhanced Characterization of the Repository Block *Cross-Drift*, involved more than 11 kilometers (8.4 miles) of tunnels and testing alcoves. Throughout this excavation, only one fracture was observed to be moist (DIRS 154565-Levich et al. 2000, p. 404); there was no active flow of water. Boreholes in the unsaturated zone identified water in the rock matrix, along faults and other fractures, and in isolated saturated zones of *perched water* (DIRS 151945-CRWMS M&O 2000, p. 8.5-1) (Figure 3-16). The water found in the pores of the rock matrix is chemically different from water found in fractures, perched water, or water in the saturated zone (DIRS 151945-CRWMS M&O 2000, pp. 8.6-1 and 8.6-2). Perched water in Yucca Mountain occurs where fractured rock overlies rock of low permeability such as unfractured rock, and upslope from faults where permeable or fractured rock lies against less permeable rock and fault fill material. Perched water bodies occur approximately 100 to 200 meters (330 to 660 feet) below the proposed repository horizon near the base of the Topopah Spring welded tuff unit (DIRS 151945-CRWMS M&O 2000, p. 8.5-10) (Figure 3-16). Water flow along fractures probably is responsible for recharging the perched water bodies. The apparent age of the perched water based on carbon-14 dating shows residence times of 3,500 to 11,000 years (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). Although there are limitations in the use of carbon-14 dating on water (such as knowing the initial activity of carbon-14, estimating sources of losses or gains, and adjusting for postnuclear age contributions), the perched water is believed to be too recent to be an accumulation of pore water from the rock matrix. Water chemistry data (discussed below) that show the perched water with different characteristics than the pore water provide additional, possibly stronger, evidence that pore water does not contribute significantly to the perched water. To learn how recently recharge might have occurred, these dating efforts also looked for the presence of tritium, which would indicate contributions from water affected by atmospheric nuclear weapons tests (after 1952). The results indicate that if tritium has reached the perched water bodies, it is in quantities too small for reliable detection (DIRS 151945-CRWMS M&O 2000, p. 5.3-30).

Hydrologic Properties of Rock. The unsaturated zone at Yucca Mountain consists of small areas of alluvium (clay, mud, sand, silt, gravel, and other detrital matter deposited by running water) and colluvium (unconsolidated slope deposits) at the surface underlain by volcanic rocks, mainly fragmented

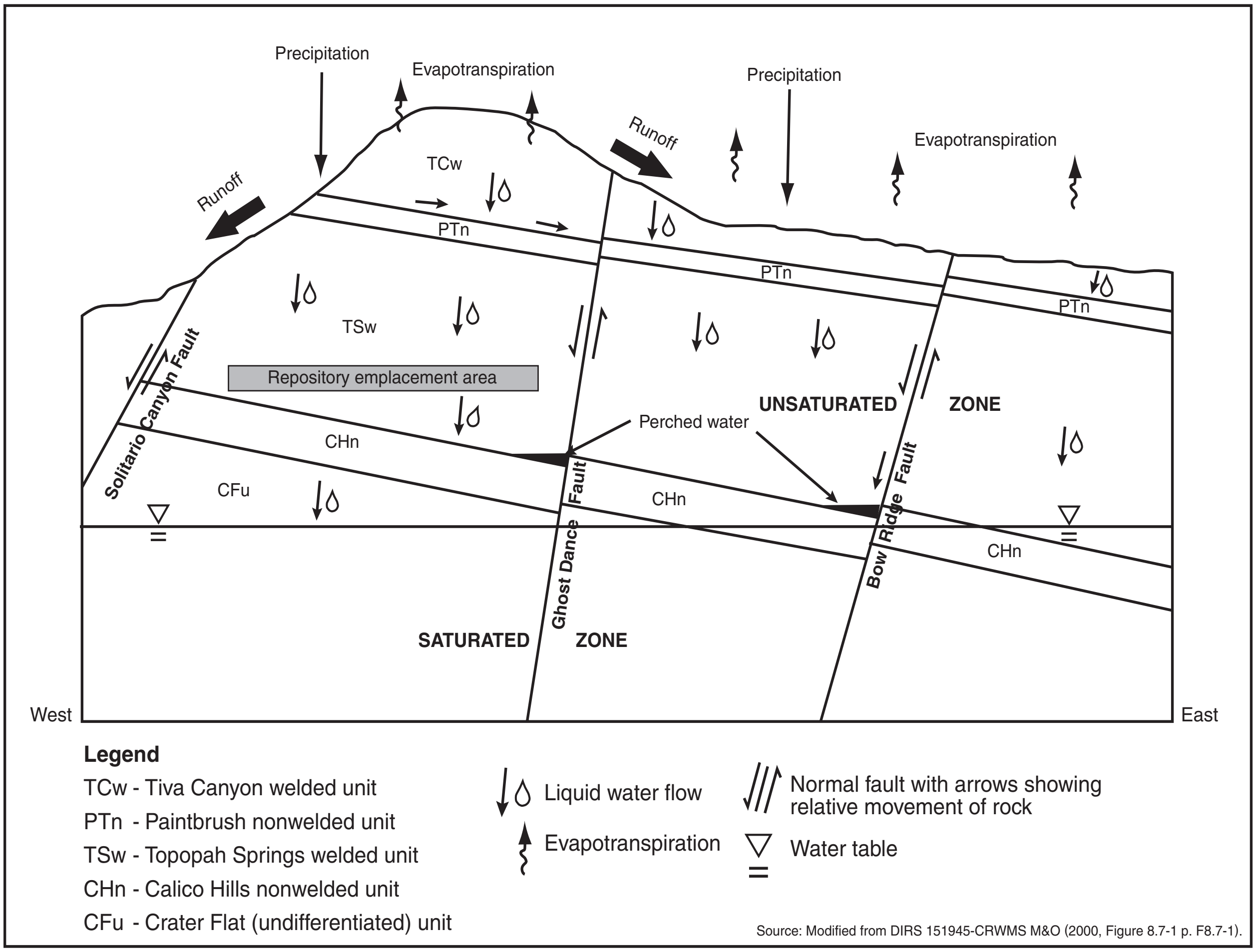

Figure 3-16. Conceptual model of water flow at Yucca Mountain.

materials called tuffs that have varying degrees of welding (DIRS 151945-CRWMS M&O 2000, p. 8.1-1). The hydrologic properties of tuffs vary widely. Some layers of tuff are welded and have low matrix porosities, but many contain fractures that allow water to flow more quickly than through the rock. Other layers, such as nonwelded and bedded tuff, have high matrix porosities but few fractures (DIRS 151945-CRWMS M&O 2000, p. 8.9-2). Some layers have many small hollow bubble-like structures (called lithophysae) that tend to reduce water flow in the unsaturated zone.

Rock units defined by a set of hydrologic properties do not necessarily correspond to rock units defined by geologic properties and characteristics. For geologic studies, rocks are generally divided on the basis of characteristics that reflect the rock origin and manner of deposition. Hydrogeologic units, on the other hand, reflect the manner in which water moves through the rock. A stratigraphic unit and a hydrogeologic unit commonly do not represent the same layer of rock. For example, a rock *stratum* classified as a single stratigraphic unit based on *lithology* or chronology, such as a tuff generated by a volcanic event, can be divided into separate hydrographic units based on hydrologic properties. Further, because the physical processes of water movement are very different under unsaturated conditions than under saturated conditions, the hydrogeologic units defined in the unsaturated zone can differ from those defined when the same rock sequence is saturated. Figure 3-17 shows the relationship between the stratigraphic units discussed in Section 3.1.3 and the hydrogeologic units discussed in this section, including the aquifers and confining units that make up the area's groundwater system. Table 3-13 lists the hydrogeologic units in the unsaturated zone at Yucca Mountain.

Era	Geologic Age	Stratigraphic unit	Approximate range of thickness (meters)	Hydrogelogic units Unsaturated	Saturated	Comments
Cenozoic Era	Quaternary and Tertiary Periods	Alluvium, colluvium, eolian deposits, spring deposits, basalt lavas, lacustrine deposits, playa deposits	**0-130**	QAL, alluvium	QTa, Valley-fill aquifer; QTc, valley-fill confining unit	QAL restricted to stream channels on Yucca Mountain; QTa occurs mainly in Amargosa Desert; major water-supply source; subsurface extent of the QTc unit is not well established
	Tertiary Period	Timber Mountain Group Rainier Mesa Tuff				Minor erosional remnants at Yucca Mountain
		Paintbrush Group Tiva Canyon Tuff	0-150	TCw Tiva Canyon welded unit		Mainly densely welded; caprock on Yucca Mountain; not known in saturated zone at or near Yucca Mountain
		(bedded tuff) Yucca Mountain Tuff Pah Canyon Tuff	20-100	PTn Paintbrush nonwelded unit		Includes bedded and nonwelded tuffs between basal part of Tiva Canyon Tuff and upper part of Topopah Spring Tuff
		Topopah Spring Tuff (vitrophyre and non-welded tuffs at base)	290-360	TSw Topopah Spring welded unit	uva, Upper volcanic aquifer	About 300 meters of densely welded tuff in unsaturated zone; host rock for repository; in saturated zone where downfaulted to east, south, and west of site
		Calico Hills Formation	150-500	CHn Calico Hills nonwelded unit	uvc, Upper volcanic confining unit	Mainly nonwelded tuff, with thin rhyolite lavas in northern site area; varies from vitric in southwest site area to zeolitic where near or below water table
		Crater Flat Group Prow Pass Tuff Bullfrog Tuff Tram Tuff	200-500	CFu Crater Flat undifferentiated unit	mva Middle volcanic aquifer	Small occurrence in unsaturated zone; widespread in saturated zone; variably welded ash-flow tuffs and rhyolite lavas; commonly zeolitized; most permeable zones are fracture-controlled
		Unnamed flow breccia Lithic Ridge Tuff	400-1,000		mvc, Middle volcanic confining unit	Nonwelded tuff, pervasively zeolitized
		Volcanics of Big Dome			lva, Lower volcanic aquifer	Lava flows and welded tuff; not known at Yucca Mountain
	(Lower Tertiary?)	Older volcanics			lvc, Lower volcanic confining unit	Nonwelded tuff, pervasively zeolitized; tuffaceous sediments in lower part
Paleozoic Era	Permian/ Pennsylvanian Periods	Bird Spring Formation Tippipah Limestone	1,000 ±		uca, Upper carbonate aquifer	Limited distribution in saturated zone north and east of Yucca Mountain
	Mississippian/ Devonian Periods	Eleana Formation (Chainman Shale)	2,500 ±		ecu, Eleana confining unit	Argillite (mudstone) and siltstone; occurrence inferred beneath volcanics of northern Yucca Mountain
	Devonian Silurian Ordovician Cambrian Periods	Devils Gate Limestone, Nevada Formation, Ely Springs Dolomite, Eureka Quartzite, Pogonip Group, Nopah Formation, Dunderberg Shale, Bonanza King Formation, Upper Carrara Formation	8,500 ±		lca, Lower carbonate aquifer	Mainly limestone and dolomite with relatively thin shales and quartzites; major regional aquifer, more than 5 kilometers (3.1 miles) thick
		Lower Carrara Formation			qcu, Precambrian confining unit	Dolomite, shale
Proterozoic (Upper Precambrian)		Proterozoic rocks				Quartzite, slate, marble; fractures commonly healed by mineralization

Source: Modified from DIRS 151945-CRWMS M&O (2000, Tables T9.3-1 and T9.3-2, Thickness date: Figures 4.5-3 and 4.5-4, pp. F4.5-3 and F4.5-4, and Table 9.2-2, pp. T9.2-2 and T9.2-3).

Figure 3-17. Correlation of generalized stratigraphy with unsaturated and saturated hydrogeologic units in the Yucca Mountain vicinity.

Table 3-13. Hydrogeologic units in the unsaturated zone at Yucca Mountain.[a]

Unit and characteristics[b]	Thickness (meters)[c]
Quaternary alluvium/colluvium Unconsolidated stream deposits beneath valleys and loose slump deposits beneath slopes; porosity and permeability medium to high.	0 - 130
Tiva Canyon welded unit (TCw) Mainly pyroclastic flow tuffs; porosity typically 10 to 30 percent; saturation commonly 40 to 90 percent.	0 - 150
Paintbrush nonwelded unit (PTn) Includes the Yucca Mountain and Pah Canyon Tuffs and uppermost part of the welded Topopah Spring Tuff; porosity generally high, 30 to 50 percent; matrix saturation, 40 to 70 percent.	20 - 100
Topopah Spring welded unit (TSw) Mainly devitrified ash flow tuff; porosity generally low, less than 20 percent, but up to 40 percent in glassy zones; matrix saturation generally greater than 50 percent, commonly greater than 80 percent.	290 - 360
Calico Hills nonwelded unit (CHn) Made up of four subunits, the lower three of which contain zeolites; the unit also includes Prow Pass Tuff (pyroclastic flow) of the Crater Flat Group; porosity generally 20 to 40 percent; matrix saturation 30 to 90 percent, commonly near 100 percent in zeolitic zones.	150 - 500
Crater Flat undifferentiated unit (CFu) Consists of welded Bullfrog Tuff (stratigraphically above) and nonwelded Tram Tuff (stratigraphically below); is below water table in much of the area, but is unsaturated beneath western part of Yucca Mountain; Bullfrog Tuff has low porosity, less than 20 percent, and high matrix saturation, close to 100 percent; Tram Tuff has porosity 20 to 40 percent; and high matrix saturation.	200 - 500

a. Source: DIRS 151945-CRWMS M&O (2000; Units and Descriptions - pp. 4.5-18 to 4.5-33 and 8.3-6 to 8.3-10; Porosity and Saturation - Figures 8.3-1 and 8.3-2, pp. F8.3-1 and F8.3-2, and Table 8.3-2, p. T8.3-3; and Thickness - Figures 4.5-3 and 4.5-4, pp. F4.5-3 and F4.5-4).
b. Letters in parentheses are used in Figures 3-16 and 3-17
c. To convert meters to feet, multiply by 3.2808.

Water Source and Movement. When precipitation falls on Yucca Mountain, part leaves as runoff, part evaporates, and part infiltrates the ground. Some of the water that infiltrates the ground eventually evaporates in the arid climate or passes to plants; the remainder percolates into the ground as infiltration.

Some of the infiltration remains at shallow levels, some eventually rises to the surface as vapor, and some (called *net infiltration*) moves deeper into the unsaturated zone. The estimated net infiltration for the current climate is 3.6 millimeters (0.1 inch) per year in a study area of about 120 square kilometers (48 square miles) that includes Yucca Mountain and 4.7 millimeters (0.2 inch) per year in the potential repository area (DIRS 151945-CRWMS M&O 2000, Tables 8.2-7 and 8.2-9, pp. T8.2-6 and T8.2-7). These are estimates of average net infiltration for fairly large surface areas. Because of the arid climate, the sporadic nature of storms, and the variation in topography, the actual amount of annual infiltration varies widely from year to year and across the area. Yucca Mountain Project studies have shown that net infiltration varies over segments of the larger areas based, in part, on the amount of unconsolidated material present. The estimated net infiltration over the study area ranges from zero where alluvium is more than 6 meters (20 feet) thick to 8 centimeters (3 inches) and more where thin alluvium overlies highly permeable bedrock (DIRS 100147-Flint, Hevesi, and Flint 1996, p. 91). On a year-to-year basis, the average net infiltration over the repository might range from 0.4 to 11.6 millimeters (0.02 to 0.5 inch) (DIRS 151945-CRWMS M&O 2000, Table 8.2-9, p. T8.2-7).

Groundwater movement in the unsaturated zone at Yucca Mountain occurs in the pore space (matrix) of rock units and along faults and fractures of rock units. Water movement through the pore space of rock units is a relatively slow (or stagnant) process compared with flow through faults and fractures (DIRS 151945-CRWMS M&O 2000, p. 8.9-10). Water movement through faults and fractures is believed to be episodic in nature (occurring at discrete times related to periods of high surface infiltration), is capable of traveling rapidly through rock units, and is the likely source of perched water in the unsaturated zone (DIRS 151945-CRWMS M&O 2000, pp. 8.9-3 to 8.9-6).

The characteristics of groundwater movement through specific rock units differ based on their hydrogeologic properties (DIRS 151945-CRWMS M&O 2000, pp. 8.9-2 to 8.9-3). Water that infiltrates into the Tiva Canyon welded unit can often be transported rapidly through fractures as deep as the underlying Paintbrush nonwelded unit. Due to its high porosity and low fracture density, the Paintbrush unit tends to slow the downward velocity of water flow dramatically in relation to highly fractured units such as the Tiva Canyon unit. However, isotopic (chlorine-36) analysis has identified isolated pathways that provide relatively rapid water movement for very small amounts of water (DIRS 151945-CRWMS M&O 2000, p. 8.12-16) through the Paintbrush nonwelded unit to the top of the underlying Topopah Springs welded unit where, due to increased fracturing, it has the potential to travel quickly through the unit.

DOE has used the ratio of chlorine-36 (a naturally occurring *isotope*) to total chlorine to determine where and when moisture has moved in the unsaturated zone at Yucca Mountain. High enough chlorine-36 ratios indicate waters exposed to very small amounts of fallout associated with above-ground nuclear weapons testing (called bomb-pulse water). The methodology used in these studies is complicated and is still under investigation; however, findings thus far have been valuable in reaching certain conclusions.

CHLORINE-36 STUDIES

These studies use the fact that a very small portion of chlorine in the atmosphere consists of the radioactive isotope chlorine-36. The production of chlorine-36 (caused in part by interactions between argon molecules and high-energy protons and neutrons in the atmosphere) is sufficiently balanced with the rate of its removal as atmospheric fallout that the ratio of chlorine-36 to stable chlorine (chlorine-35 and -37) at any given location remains fairly constant in atmospheric salts deposited on land, such as that dissolved in rainwater. Once chlorine is isolated from the surface environment (as when dissolved in water percolating down through the soil and subsurface rocks), subsequent changes in the chlorine-36-to-total-chlorine ratio can be attributed to decay of the chlorine-36 (DIRS 101005-Levy et al. 1997, p. 2) (that is, if the residence times are long enough in relation to the 301,000-year half-life of this radionuclide). Measuring the chlorine-36-to-total-chlorine ratio in underground water or in residues it leaves behind, and knowing what the ratio was at the time of recharge provides a means of estimating the age of the water. In reality, slight variations over time in the atmospheric ratio and the potential for some minor production of chlorine-36 in the subsurface has made the use of this technique for water dating difficult, and its use is still under investigation. However, the atmospheric ratio of chlorine-36 to total chlorine has increased by orders of magnitude as a result of above-ground nuclear testing during the past 50 years. As a consequence, the technique has been very successful in tracing underground water or water residues that originated at the surface within the past 50 years, with the so-called *bomb-pulse signal* indicating very young water.

Chlorine-36 analyses at Yucca Mountain have identified locations where water has moved fairly rapidly (in several decades) from the surface to the depth of the proposed repository and also where it has moved very slowly (thousands to tens of thousands of years). The chlorine-36 studies included one study that collected 247 rock samples along the 8-kilometer (5-mile) Exploratory Studies Facility tunnel (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). About 70 percent of the samples were from areas thought to be more likely to show evidence of rapid water movement [that is, areas of broken rock such as faults, fractures, or breccia zones (areas where rock composed of fragments of older rocks melded together)] (DIRS 100144-Fabryka-Martin et al. 1997, p. 4-13).

Most of the samples (77 percent) had ratios that were ambiguous in that they fell within the range over which the chlorine-36-to-total-chlorine ratio has varied over the last 30,000 years or more (DIRS 100144-Fabryka-Martin et al. 1997, p. 3-1). Results of these samples indicate that the groundwater travel times from the surface to the repository depth in most areas probably are thousands to tens of thousands of years. This is because there is little evidence for measurable radioactive decay of the chlorine-36 signal in the subsurface. However, a few samples indicated ratios low enough to suggest the possible presence of zones of relatively old or stagnant water.

About 13 percent of the samples (31 samples) had high enough chlorine-36-to-total-chlorine ratios to indicate the water originated from precipitation occurring in the past 50 years (that is, nuclear age precipitation) (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). Locations where bomb-pulse water occurred were correlated with the physical conditions in the mountain and on the surface that could lead to, or otherwise affect, the findings. The conclusion to date of these ongoing studies is that relatively fast transport of water through the mountain is controlled by the following factors (DIRS 104878-CRWMS M&O 1998, p. 3-2):

- The presence of a continuous fracture path from the surface: The limiting factor is a fracture or fault cutting the Paintbrush nonwelded bedded tuffs (PTn) hydrogeologic unit (this prominent unit is above the repository horizon; see Figure 3-16 and Table 3-13). Fracture pathways are normally available in the welded portions of the overlying Tiva Canyon and underlying Topopah Spring units. This is consistent with hydrologic modeling of *percolation* through this nonwelded bedded tuff, which indicates that there must be fracture pathways due to faulting or other disturbances for water to travel through this unit in 50 years or less. Section 3.1.3 discusses fault locations inside Yucca Mountain.

- The magnitude of surface infiltration: There must be enough infiltration to sustain a small component of flow along the connected fracture pathway.

- The residence time of water in the soil cover: This time must be less than 50 years; to achieve this, the depth of the soil overlying the fracture pathway must be less than an estimated 3 meters (10 feet).

Several important factors affect a discussion of chlorine-36 studies. Ratios of naturally occurring radioactive chlorine-36 to the other isotopes of chlorine are on the order of one chlorine-36 atom to approximately two trillion (2,000,000,000,000) other chlorine atoms. Samples designated as showing evidence of elevated, "bomb-pulse" chlorine-36 still have exceedingly minute amounts of this isotope, containing only two to eight times the amount that occurs naturally. The scale of these measurements and the significance being placed on them makes understanding the sources of chlorine-36 in the underground environment and the intricacies of the analytical procedures extremely important. To ensure the correct interpretation of this subtle chemical signal (that is, of elevated amounts of chlorine-36), studies are underway to determine whether independent laboratories and related isotopic studies corroborate the findings.

Water percolating to the depth of the repository and beyond is affected not only by fractures but also by the nature of the hydrogeologic units it encounters. Pressure testing in boreholes indicates that fractures in the Topopah Spring tuff (the rock unit in which DOE would build the repository) are very permeable and extensively interconnected (DIRS 151945-CRWMS M&O 2000, p. 8.12-5). Below the repository level, low-permeability zones impede the vertical flow of water in the Calico Hills nonwelded unit (which includes the basal part of the Topopah Springs Tuff, Figure 3-17), forming perched water bodies (DIRS 151945-CRWMS M&O 2000, pp. 8.9-5 and 8.9-6). The primary source of the perched water is water traveling down along faults and fractures. In the dipping or sloped strata beneath Yucca Mountain, perched water bodies require vertical impediments such as fault zones where less permeable rock and fault-gouge material block the lateral flow of water (Figure 3-16). If these conditions do not exist at the fault zone, the fault can provide a downward pathway. Even in cases where fault zones are barriers to lateral water flow, they can be very permeable to gas and moisture flow along the fault plane and permit the rapid vertical flow of water from the land surface to great depth. Studies of heat flux above and below the perched water zone appear to indicate more water percolation above the perched water than below (DIRS 100627-Bodvarsson and Bandurraga 1996, p. 21). This is consistent with the concept that some of the water moves laterally on top of the low-permeability zone before it resumes its downward course to the saturated zone.

DOE has recently undertaken development of what is termed an “expected-case” model of groundwater flow in the unsaturated zone as reported in DIRS 156609-BSC (2001, all). One of the objectives of this effort was to evaluate the impact of the conservatism in the Total System Performance Assessment (TSPA) modeling (see Chapter 5 and Appendix I). The study examined the flow and transport models used in the TSPA effort to identify areas where conservatism could be reduced and uncertainty better characterized. The result is a model of unsaturated zone flow that DOE believes is more realistic than the conservative one. The expected-case model was run under several varying conditions, including runs assuming a nonsorbing tracer, which moves like water, was released at the level of the proposed repository. The results indicate it would take in the range of 7,000 to 8,000 years for 50 percent of the tracer to reach the underlying water table (DIRS 156609-BSC 2001, Figure 6.5-29, p. 183). Some of the tracer would find its way to faster pathways to the water table; some would take longer to travel the distance. Several different conceptual models of groundwater movement in the unsaturated zone were integrated into runs of the numerical mode. DOE believes the most likely case, as described here, presents an estimate of groundwater travel time from the proposed repository to the water table that is a reasonable representation of what occurs in the natural setting.

Unsaturated Zone Groundwater Quality. DOE has analyzed water from the unsaturated zone, both pore water from the rock matrix and perched water, to obtain information on the mechanisms of recharge and the amount of connection between the two. The preceding sections discuss some of the relevant findings.

Table 3-14 summarizes the chemical composition of perched and pore water samples from the vicinity of Yucca Mountain.

Table 3-14. Water chemistry of perched and pore water samples in the vicinity of Yucca Mountain.[a]

Constituent	Ranges of chemical composition: Perched	Pore
pH	7.6 - 8.7	7.7 - 8.4
Total dissolved solids (milligrams per liter)	140 - 330	320 - 360
Calcium (milligrams per liter)	2.9 - 45	1.1 - 62
Magnesium (milligrams per liter)	0 - 4.1	0 - 4.5
Potassium (milligrams per liter)	1.7 - 10	N/A[b]
Sodium (milligrams per liter)	34 - 98	49 - 140
Bicarbonate (milligrams per liter)	110 - 220	170 - 230
Chloride (milligrams per liter)	4.1 - 16	26 - 90
Bromide (milligrams per liter)	0 - 0.41	0
Nitrate (milligrams per liter)	0 - 34	11 - 17
Sulfate (milligrams per liter)	4 - 220	14 - 45

a. Source: DIRS 104951-Striffler et al. (1996, Table 2).
b. N/A = not available.

The smaller concentrations of dissolved minerals, particularly chloride, in perched water in comparison to those in pore water is a primary indicator of differences between the two. This difference in dissolved mineral concentrations indicates that the two types of water do not interact to a large extent and that the perched water reached its current depth with little interaction with rock. This, in turn, provides strong evidence that flow through faults and fractures is the primary source of the perched water (DIRS 151945-CRWMS M&O 2000, p. 5.4-2).

Saturated Zone

Water Occurrence. The saturated zone at Yucca Mountain has three aquifers and two confining units. The aquifers are commonly referred to as the upper volcanic aquifer, the lower volcanic aquifer, and the lower carbonate aquifer. The interlayered aquitards (low permeability units that retard water movement) that separate the aquifers are called the upper volcanic confining unit and the lower volcanic confining unit (see Figure 3-17). The upper volcanic aquifer is composed of the Topopah Spring welded tuff, which occurs in the unsaturated zone near the repository but is present beneath the water table to the east and south of the proposed repository. The upper volcanic confining unit includes the vitrophyre and nonwelded tuffs at the base of the Topopah Spring Tuff, the Calico Hills nonwelded unit, and the uppermost unstructured end of the Prow Pass tuff where they are saturated. The lower volcanic aquifer includes most of the Crater Flat Group, and the lower volcanic confining unit includes the lowermost Crater Flat Group and deeper tuff, lavas, and flow breccias. An upper carbonate aquifer, though regionally important, is not known to occur beneath Yucca Mountain. (The lower volcanic aquifer discussed here corresponds to the middle volcanic aquifer shown in Figure 3-17. The lower volcanic aquifer in Figure 3-17 has not been identified in the area of the proposed repository.)

TYPES OF TUFF

Welded tuff results when the volcanic ash is hot enough to melt together and is further compressed by the weight of overlying materials.

Non-welded tuff results when volcanic ash cools in the air sufficiently that it does not melt together, yet later becomes rock through compression.

South of the proposed repository site, downgradient in the groundwater flow path from Yucca Mountain, the Tertiary volcanic rocks (and the volcanic aquifers) pinch out and groundwater moves into the valley-fill sediments of the Amargosa Desert (DIRS 151945-CRWMS M&O 2000, p. 9.3-80). Figure 3-18, which is a generalized hydrogeologic cross-section from Yucca Mountain to the northern portion of the Amargosa Desert, shows the relative positions of these aquifers. In the Amargosa Desert south of Yucca Mountain, the most important source of water is an aquifer formed by valley-fill deposits (DIRS 151945-CRWMS M&O 2000, p. 9.2-23).

The lower carbonate aquifer is more than 1,250 meters (4,100 feet) below the proposed repository horizon (DIRS 151945-CRWMS M&O 2000, Table 9.3-8, p. T9.3-10). This aquifer, which consists of lower Paleozoic carbonate rocks (limestone and dolomite) that have been extensively fractured during many periods of mountain building (see Section 3.1.3), forms a regionally extensive aquifer system through which large amounts of groundwater flow (DIRS 151945-CRWMS M&O 2000, p. 9.2-8). Evidence indicates that water in the lower carbonate aquifer is at least as old as most of the water in the volcanic aquifers (with apparent ages in the range of 10,000 to 20,000 years) (DIRS 151945-CRWMS M&O 2000, pp. 9.2-57 and 9.6-4) and, similarly, was recharged during a wetter and cooler climate (DIRS 151945-CRWMS M&O 2000, p. 9.6-4). Some of the limited carbonate aquifer sample results indicate older water ages (up to 30,000 years), but use of carbon-14 dating on this water has an additional limitation due to the probable contribution of "dead carbon" (nonradioactive) dissolved from the carbonate rock (DIRS 151945-CRWMS M&O 2000, p. 9.2-57).

Main Index

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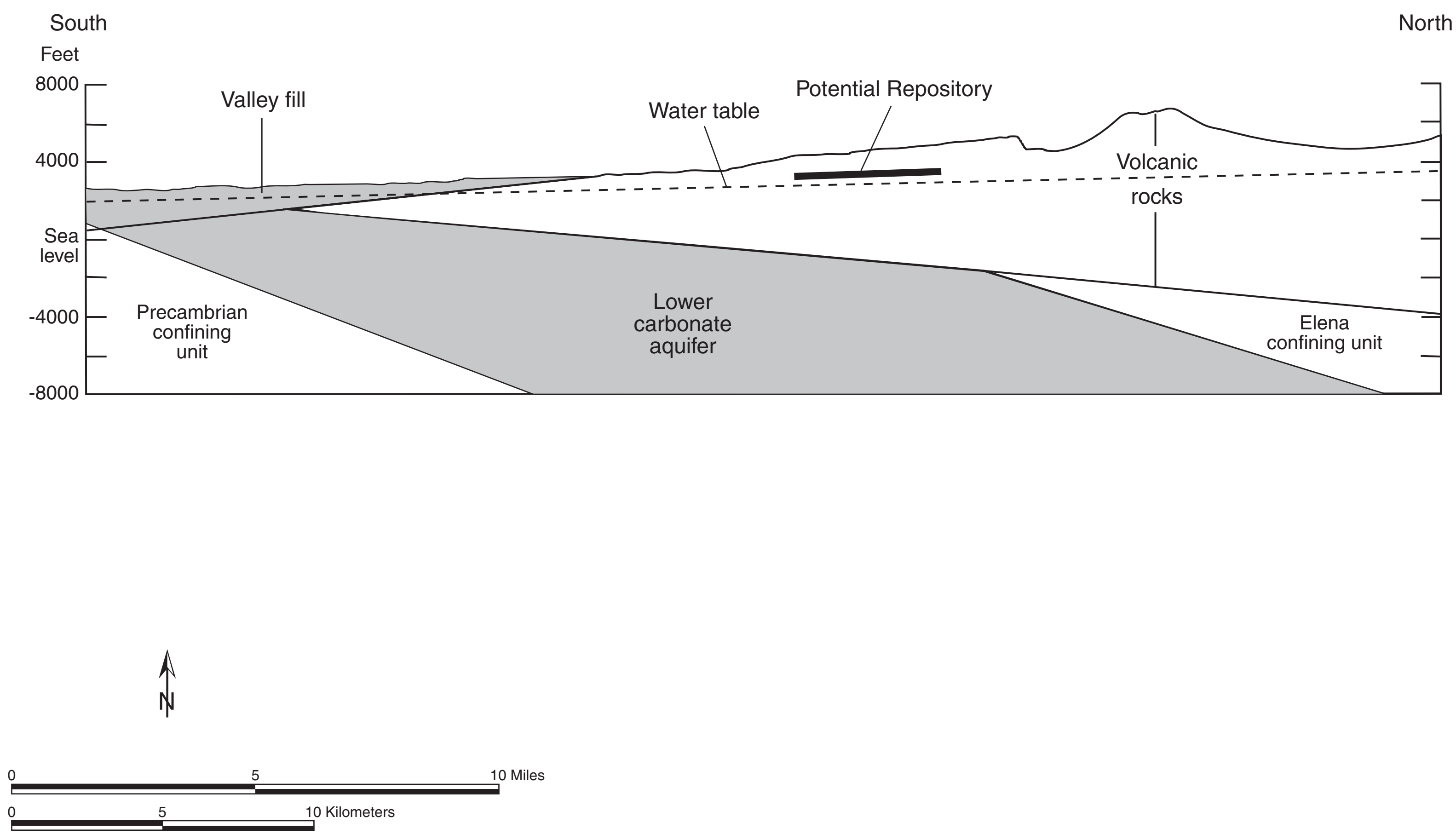

Source: Modified from DIRS 151945-CRWMS M&O (2000, Figure 9.3-4, p. F9.3-4).

Figure 3-18. Cross section from Northern Yucca Mountain to Northern Amargosa Desert, showing generalized geology and the water table.

Limited data at Yucca Mountain show that the level to which water rises in a well that penetrates the lower carbonate aquifer is about 20 meters (66 feet) higher than the water levels in the overlying volcanic aquifers (DIRS 151945-CRWMS M&O 2000, p. 9.3-34). Four other wells at Yucca Mountain that penetrate as deep as the lower volcanic confining unit (the unit above the carbonate aquifer), show higher potentiometric levels in that unit than in overlying volcanic aquifers. This might be an indication of the upward hydraulic gradient in the carbonate aquifer (DIRS 100465-Luckey et al. 1996, p. 29). One of the wells for the Nye County Early Warning Drilling Program, which is about 19 kilometers (12 miles) south of the repository site, also penetrated the carbonate aquifer and shows it to have an upward gradient. At this location, water in the carbonate aquifer well rises 8 meters (26 feet) higher than the water level in the overlying volcanic aquifer (DIRS 155950-BSC 2001, pp. 12-12 and 12-13, and Figure 12.3.2-1, p. 12F-4). This indicates that, in the vicinity of Yucca Mountain, and in areas to the south, water from the lower carbonate aquifer is pushing up against a confining layer with more force than the water in the upper aquifers is pushing down. This suggests that water in the volcanic aquifers does not flow down into the lower carbonate aquifer at Yucca Mountain because it would be moving against a higher upward pressure and that, if mixing occurs, it would be from carbonate to volcanic and not the reverse.

Paleoclimatic (referring to the climate during a former period of geologic time) studies have identified five wetter and cooler periods in the southern Great Basin during the past 400,000 years (late Pleistocene). These periods occurred 10,000 to 50,000 years ago; 60,000 to 70,000 years ago; 120,000 to 170,000 years ago; 220,000 to 250,000 years ago; and 330,000 to 400,000 years ago. They represent the sequencing of glacial (cooler and wetter) to interglacial (warmer and drier) and back to glacial climates (DIRS 151945-CRWMS M&O 2000, p. 6.3-19). Calcite veins and opal were deposited along fractures during the wetter periods. The calcite and opal coatings have been dated by the uranium series method; the calcites have also been dated by the carbon-14 method. The youngest vein deposits are 16,000 years old (DIRS 151945-CRWMS M&O 2000, p. 6.3-33). During the wetter periods, the estimated regional water table was a maximum of 120 meters (390 feet) above the present level beneath Yucca Mountain during the past million or more years based on mineralogic, isotopic, and discharge deposit data and on hydrologic modeling analysis. The water table could rise by an estimated 50 to 130 meters (160 to 430 feet) from current levels under hypothetical future wetter climate conditions (DIRS 137917-CRWMS M&O 2000, p. 9.4-24). The proposed repository drift layouts would all be well above these historic and possible future maximum water table elevations (see Section 2.1). The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, pp. 6.3-1 to 6.3-39) provides additional information, including supporting evidence, on the timing, magnitude, and character of past climate changes in the Yucca Mountain region.

Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically higher than 120 meters (390 feet) above the current level, even reaching the land surface in the past (DIRS 106963-Szymanski 1989, all). If such an event occurred, it would affect the performance of the proposed repository. These concerns originated in the early- to mid-1980s when surface excavations performed as part of site investigations exposed vein-like deposits of calcium carbonate and opaline silica (DIRS 151945-CRWMS M&O 2000, p. 4.4-25). DIRS 106963-Szymanski (1989, all) hypothesized that the carbonate and silica were deposited by hydrothermal fluids, driven to the surface by pressurization of groundwater by earthquakes (a mechanism called *seismic pumping*) or by thermal processes that occurred in the Yucca Mountain vicinity. A number of investigators and groups, including a National Academy of Science panel specifically designated to look at the issue (DIRS 105162-National Research Council 1992, all), have examined the model on which this position is based and have rejected its important aspects (DIRS 100465-Luckey et al. 1996, pp. 76 to 77). The National Research Council panel concluded that the evidence cited as proof of groundwater upwelling in Yucca Mountain and in its vicinity could not reasonably be attributed to that process. In addition, the panel stated its position that the proposed mechanism for upwelling water was inadequate to raise the water table more than a few tens of meters (DIRS 101779-DOE 1998, Volume 1, p. 2-26). Finally, the panel concluded that the carbonate-rich depositions in fractures were formed from surface water from precipitation and surface processes (DIRS 151945-CRWMS M&O 2000, p. 4.4-36).

Another alternative interpretation of past groundwater levels at Yucca Mountain occurs in DIRS 104875-Dublyansky (1998, all). This study involved the examination of tiny pockets of water (known as *fluid inclusions*) trapped in the carbonate-opal veinlets deposited in rock fractures at Yucca Mountain. According to the report, an analysis of samples collected from the Exploratory Studies Facility includes evidence of trace quantities of hydrocarbons and evidence that the fluid inclusions were formed at elevated temperatures. These findings, and others, are used to support the report's conclusion that the carbonate-opal veinlets were caused by warm upwelling water and not by the percolation of surface water. DOE, given the opportunity to review a preliminary version of the report, arranged for review by a group of independent experts, including U.S. Geological Survey personnel and a university expert. This review group did not concur with the conclusion in the report by DIRS 104875-Dublyansky (1998, all), which now contains an appendix with the DOE-arranged review comments and the author's responses. Although DOE disagreed with some of the central scientific conclusions presented in this report, both parties agreed that additional research was needed to resolve the issue. As a result, DOE supported an independent investigation by the University of Nevada at Las Vegas, in which both the U.S. Geological Survey and the State of Nevada were invited to participate. This independent effort to analyze mineral samples from Yucca Mountain is not yet final, but University researchers presented papers on their preliminary findings at a November 2000 meeting of the Geological Society of America. They reported (DIRS 154280-Wilson et al. 2000, all) that evidence was present of fluid inclusions being formed at elevated temperature, but generally in the older (basal) part of the samples. Uranium-lead dating of the minerals in the younger outer surfaces, where there was no such evidence, indicates these minerals began precipitating between 3.8 and 1.9 million years ago. As a result, the study concluded that passage of fluids with elevated temperatures occurred prior to that time.

Opposing viewpoints dealing with the analysis of mineral samples from Yucca Mountain were presented at the same meeting of the Geological Society of America. One paper (DIRS 154790-Pashenko and Dublyansky 2000, all) reiterated the position that the apparent deposition temperatures of fluid inclusions were simply too high to be attributed to descending rainwater. Another (DIRS 154789-Dublyansky 2000, all) pointed to the diversity in the make-up of the mineral deposits as another piece of evidence suggesting a low-temperature hydrothermal (upwelling) origin. DOE and the State of Nevada are continuing to evaluate these and other alternative conceptual models and data interpretations.

Hydrologic Properties of Rock. This section discusses the hydrologic properties of rock in the saturated zone, and specifically the aquifers and confining units at Yucca Mountain. As discussed above, these properties depend in part on whether the rocks are saturated. In general, the amount and speed at which water flows through an aquifer depend chiefly on the transmissivity and effective porosity of the rock. *Transmissivity* is a measure of how much water an aquifer can transfer and is equal to the average hydraulic conductivity of the aquifer multiplied by the thickness of the aquifer that is saturated. *Hydraulic conductivity* is the volume of water moving in an aquifer during a unit of time through a unit of area that is perpendicular to the direction of flow. *Porosity* is the ratio of the rock's void (open) space to its total volume; *effective porosity* is the ratio of interconnected void space to total volume.

Figure 3-19 shows the types of conditions that might exist in gravel and rock aquifers that would make them more or less permeable to water movement. The empty spaces between gravel fragments or in the rock fractures represent the porosity. Although not necessarily representative of conditions at Yucca Mountain, the figure shows that the manner in which void spaces are interconnected, more than their size or quantity, determines how water can move through the material. At Yucca Mountain, conditions are often such that the rock with the highest porosity is also the rock with the fewest fractures (DIRS 151945-CRWMS M&O 2000, p. 9.2-7). Because the void spaces are not interconnected very well, such a high-porosity rock has low transmissivity. Because a large portion of the groundwater flow at Yucca Mountain

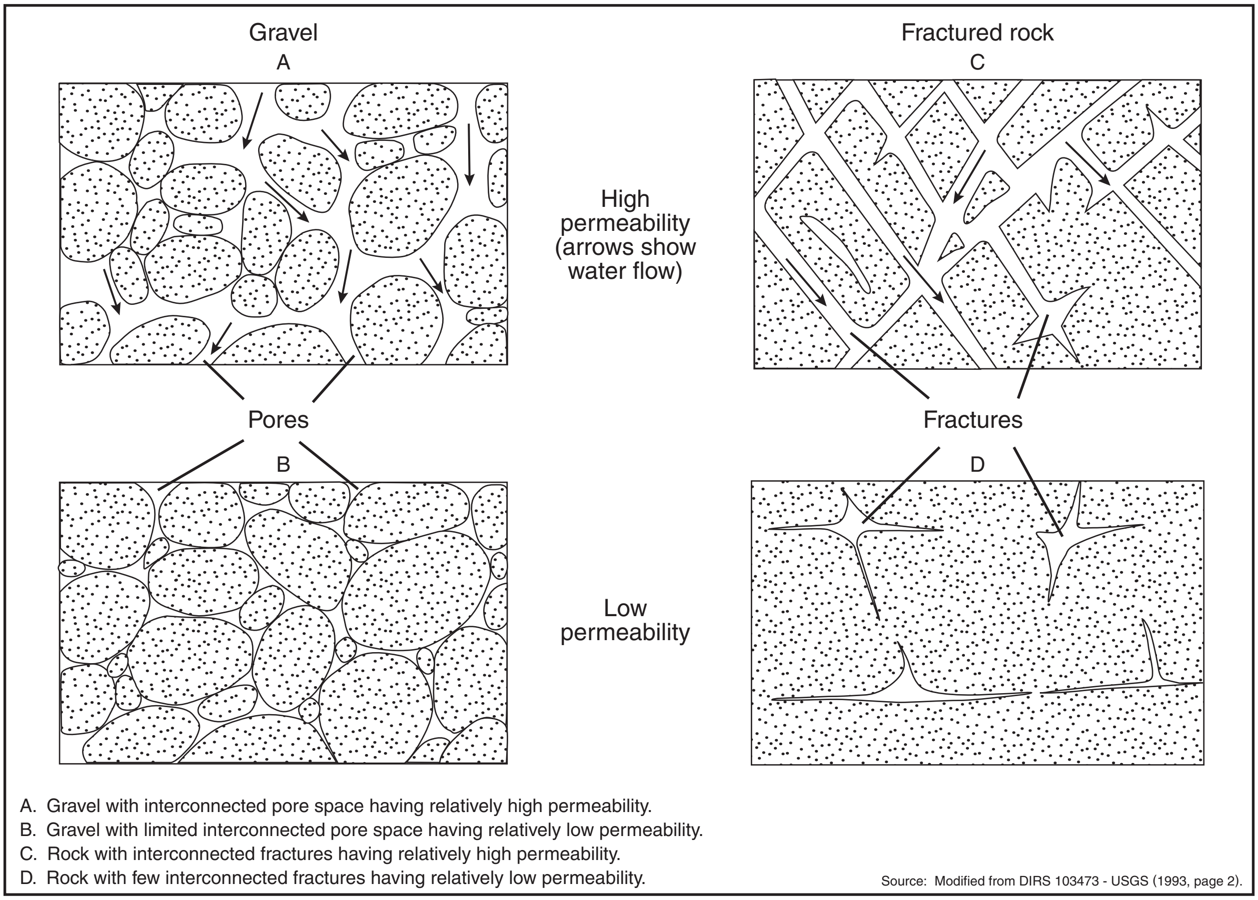

Figure 3-19. Aquifer porosity and effects on permeability.

is probably along fractures, representative transmissivity values are difficult to measure. Measurements can vary greatly depending on the nature of the fractures that happen to be intercepted by the borehole and the location in the borehole at which measurements are made. This is reflected in the wide range of transmissivity values listed in Table 3-15, which also lists the characteristics, thicknesses, apparent hydraulic conductivities, and porosities of the three aquifers and two confining units beneath Yucca Mountain. For the lower carbonate aquifer, the table lists a single transmissivity value because there was only a single test for that unit. Similarly, only one apparent hydraulic conductivity value, which is a measure of the aquifer's capacity to transport water, is provided for the lower carbonate aquifer unit because it is based on tests in a single well at Yucca Mountain. However, the value is an average of measurements taken from that well. This and the other hydraulic conductivity values are called *apparent* because they are all based on single-borehole tests. Such measurements, which are believed to represent conditions at a limited distance around the well, could vary greatly depending on whether there are water-bearing fractures in the well zone being tested. When such fractures are present, hydraulic properties measured in a single-borehole test probably reflect conditions only in isolated locations rather than in the overall rock matrix in the test zone.

Water Source and Movement. Section 3.1.4.2.1 describes the direction of water movement (Figure 3-15), the nature of the rock through which it moves, and where local recharges to and discharges from the aquifer might occur.

When undisturbed by pumping, groundwater levels at Yucca Mountain have been very stable. A Geological Survey study of water levels over 10 years (1985 to 1995) indicated water levels did not change by season and most water-level fluctuations are probably due to changes in barometric pressure

Table 3-15. Aquifers and confining units in the saturated zone at Yucca Mountain.

Unit	Typical thickness (meters)[a,b,c]	Transmissivity (square meters per day)[d,e]	Apparent hydraulic conductivity (meters per day)[e]	Typical porosity[f,g] (ratio)
Upper volcanic aquifer Densely welded and densely fractured part of Topopah Spring Tuff	300	120 - 1,600	0.13 - 19	0.05 - 0.10
Upper volcanic confining unit Basal vitrophyre of Topopah Spring Tuff, Calico Hills Formation Tuff, and uppermost nonwelded part of Prow Pass Tuff	90 - 330	2.0 - 26	0.02 - 0.26	0.l9 - 0.28
Lower volcanic aquifer Most of Prow Pass Tuff and underlying Bullfrog and Tram Tuffs of Crater Flat Group	370 - 700	1.1 - 3,200	< 0.0037 - 13	0.19 - 0.24
Lower volcanic confining unit Bedded tuffs, lava flows, and flow breccia beneath Tram Tuff	370 - > 750	0.003 - 23	5.5×10^{-6} - 0.11	0.15 - 0.24
Lower carbonate aquifer Cambrian through Devonian limestone and dolomite	N/A[h]	120	0.19	0.003 - 0.05

a. Source: DIRS 100465-Luckey et al. (1996, Table 2 and Figure 7).
b. To convert meters to feet, multiply by 3.2808.
c. Typical thickness ranges for the upper volcanic confining unit, the lower volcanic aquifer, and the lower volcanic confining unit are based on measurements from 13 boreholes. With respect to the lower volcanic confining unit, only one penetrated and showed a unit thickness of about 370 meters (1,200 feet); of the others, about 750 meters (2,500 feet) was the deepest penetration without passing through. Water was detected in the rock unit that elsewhere makes up the upper volcanic aquifer unit in only one of the 13 boreholes. (Beneath the center of Yucca Mountain, the upper volcanic aquifer is above the saturated zone.) The typical thickness shown here for this unit is based on Figure 7 from DIRS 100465-Luckey et al. (1996, Figure 7).
d. To convert square meters to square feet, multiply by 10.764.
e. Source: DIRS 151945-CRWMS M&O (2000, Tables 9.3-4 and 9.3-5, pp. T9.3-6 and T9.3-7).
f. Source: DIRS 151945-CRWMS M&O (2000, pp. 9.3-10 to 9.3-17).
g. Ranges are for means of several hydrogeological subunits.
h. N/A = not available.

and Earth tides (DIRS 151945-CRWMS M&O 2000, p. 9.3-30). In addition, short-term fluctuations in groundwater elevations also have been attributed to apparent recharge events and earthquakes. Water levels in wells have fluctuated by as much as 0.9 meter (3 feet) in response to earthquake events, and confined water pressure deep in wells fluctuated by as much as 2.2 meters (7 feet) in response to those same events. However, the fluctuations are typically of short duration with water levels returning to the pre-earthquake conditions within minutes to a few hours (DIRS 151945-CRWMS M&O 2000, pp. 9.4-20 and 9.4-21). An exception to this occurred in response to earthquakes in the summer of 1992, when water levels in specific wells at Yucca Mountain fluctuated over several months.

At the northern end of Yucca Mountain, the apparent potentiometric surface slopes steeply southward, dropping almost 300 meters (980 feet) in a horizontal distance of about 2 kilometers (1.2 miles) (DIRS 151945-CRWMS M&O 2000, pp. 9.2-46 and 9.3-31). Experts reviewing the data have suggested several credible reasons for this large gradient, including that it results from an undetected geological feature with low permeability, that it is caused by groundwater draining to deep aquifers, or that it is a perched water table being encountered in this area (DIRS 100353-CRWMS M&O 1998, pp. 3-5 and 3-6). However, there are no obvious geologic reasons for the large gradient, and it is still under investigation.

The north-trending Solitario Canyon fault, on the west side of Yucca Mountain, apparently impedes the eastward flow of groundwater in the saturated zone. West of the fault, the water table slopes moderately about 40 meters (130 feet) in less than 1 kilometer (0.6 mile), while east of the fault the water table slopes very gently, changing by only 0.1 to 0.3 meter per kilometer (0.5 to 1.6 feet per mile) (DIRS 151945-CRWMS M&O 2000, pp. 9.3-38 to 9.3-40, and Figure 9.3-15, p. F9.3-15). West of the Solitario Canyon fault groundwater probably flows southward either along the fault or beneath Crater Flat.

The gentle southeastward groundwater gradient east of the Solitario Canyon fault underlies the proposed repository horizon and extends beneath Fortymile Wash and probably farther east into Jackass Flats. This gentle gradient might indicate that the rocks through which the water flows are highly transmissive, that only small amounts of groundwater flow through this part of the system, or a combination of both. This gentle southeastward gradient is a local condition in the regional southward flow of the groundwater.

In an opposing viewpoint about the stability of groundwater levels at Yucca Mountain, DIRS 103180-Davies and Archambeau (1997, pp. 33 and 34) suggests that a moderate magnitude earthquake at the site could cause a southward displacement of the large hydraulic gradient to the north of the proposed repository, resulting in a water table rise of about 150 meters (490 feet) at the site. In addition, that report proposed that a severe earthquake could cause a rise of about 240 meters (790 feet) in the water table, flooding the repository. As part of its study of groundwater flow in the saturated zone, DOE elicited expert opinions on various issues from a panel of five experts in the fields of groundwater occurrence and flow. Among the issues put to the panel were those raised by DIRS 103180-Davies and Archambeau (1997, all). The panel reviewed the Davies and Archambeau paper and received briefings by project personnel and outside specialists. The consensus of the panel was that a rise of the groundwater to the level of the proposed repository was essentially improbable and that changes to the water table associated with earthquakes would be neither large nor long-lived (DIRS 100353-CRWMS M&O 1998, p. 3-14).

Inflow to Volcanic Aquifers at Yucca Mountain. There are four potential sources of inflow to the volcanic aquifers in the vicinity of Yucca Mountain: (1) lateral flow from volcanic aquifers north of Yucca Mountain, (2) recharge along Fortymile Wash from occasional stream flow, (3) precipitation at Yucca Mountain, and (4) upward flow from the underlying carbonate aquifer. The actual and relative amounts of inflow from each source cannot be measured directly on any large-scale basis. However, estimates have been generated based on data collected and tests performed at individual locations and from incorporation of these data into regional- and site-scale models of the unsaturated and saturated zones.

North of Yucca Mountain, the potentiometric surface rises steeply toward probable recharge areas on Pahute Mesa (Figure 3-15) and Rainier Mesa. Chemical data indicate that some recharge to the groundwater has occurred everywhere in the Yucca Mountain vicinity during the past 10,000 years, but that most recharge occurred between 10,000 and 20,000 years ago (based on apparent carbon-14 ages) during a wetter climate (DIRS 151945-CRWMS M&O 2000, p. 9.3-53). From west to east across Yucca Mountain, the age of water in the saturated zone decreases from about 19,000 years to 9,100 years (DIRS 101036-Benson and McKinley 1985, p. 4).

One estimate of the annual recharge along a 42-kilometer (26-mile) segment of Fortymile Wash in the area of Yucca Mountain is about 110,000 cubic meters (88 acre-feet) (DIRS 151945-CRWMS M&O 2000, pp. 7.2-1 and 7.2-2). Much of the recharge occurs during and after heavy precipitation when water flows in the wash. On rare occasions, Fortymile Wash carries water to Jackass Flats and into the Amargosa Desert. After periods of flow in Fortymile Wash during 1983, 1992, 1993, and 1995 water levels in nearby wells rose as a result of infiltration (DIRS 151945-CRWMS M&O 2000, p. 7.2-2). Earlier studies found that shallow water in some wells was younger than water deeper in the wells, indicating that recharge was occurring (DIRS 151945-CRWMS M&O 2000, p. 9.3-53). Paleoclimatic evidence suggests that perennial water was present in Fortymile Wash 50,000 years ago (DIRS 105162-National Research Council 1992, Appendix C, p. 198), and that substantial recharge might have occurred as recently as 7,000 to 15,000 years ago (DIRS 151945-CRWMS M&O 2000, p. 9.3-53).

Recharge to the saturated zone below Yucca Mountain from precipitation is small in comparison to inflow from volcanic aquifers to the north or recharge along Fortymile Wash (see the unsaturated zone discussion). An average net infiltration of 4.7 millimeters (0.2 inch) over a 4.7-square-kilometer (1.8-square-mile) repository footprint would produce a quantity of recharge about 20 percent of the estimated annual recharge along the nearby 42-kilometer (26-mile) segment of Fortymile Wash.

Monitoring well data collected during the site characterization effort have shown that the potentiometric surface of the carbonate aquifer (that is, the level to which water rises in wells tapping this aquifer), at least in the immediate vicinity of Yucca Mountain, is higher than the water level in the overlying volcanic aquifer. Based on this and other considerations, studies suggest that, provided structural pathways exist, the lower carbonate aquifer might provide upward flow to the volcanic aquifer beneath the proposed level of the repository and farther south. The amount of inflow, if it occurs, is not known.

Outflow from Volcanic Aquifers at and Near Yucca Mountain. Pathways by which water might leave the volcanic aquifers in the Yucca Mountain vicinity include (1) downgradient movement into other volcanic aquifers and alluvium in the Amargosa Desert, (2) downward movement into the carbonate aquifer (though evidence indicates that this does not occur), and (3) upward movement into the unsaturated zone. In addition, water is pumped from wells for a variety of uses, as described in Section 3.1.4.2.1. With the exception of well withdrawals, the actual and relative amounts of outflow from each source are not known.

The regional slope of the potentiometric surface indicates that much of the groundwater flowing southward beneath Yucca Mountain discharges about 60 kilometers (37 miles) to the south at Alkali Flat (Franklin Lake Playa) and in Death Valley. Death Valley, more than 80 meters (260 feet) below sea level, is the final sink for surface water and groundwater in the Death Valley regional groundwater flow system (Figure 3-13); as such, water leaves only by evapotranspiration. Therefore, the pathway for groundwater beneath Yucca Mountain, as indicated by the potentiometric surface, is southerly where it traverses portions of the volcanic aquifers before encountering the basin-fill alluvium and carbonate rock that underlie the Amargosa Desert.

Outflow from the volcanic aquifers into the underlying carbonate aquifer might occur, but direct evidence for this does not exist. Studies suggest that the steeply sloping potentiometric surface at the north end of Yucca Mountain could be explained by a large outflow from the volcanic aquifers to the carbonate aquifer. However, in the vicinity of Yucca Mountain, data available on the potentiometric head of the carbonate aquifer indicate that the opposite condition (that is, outflow from the carbonate aquifer up to the volcanic aquifer) is more likely.

The third possible pathway of outflow from the volcanic aquifer (that is, upward movement to the unsaturated zone), if present, has not been quantified. However, consistent with the above discussion of net infiltration, DOE believes that there is a net downward movement of water in the unsaturated zone in the vicinity of Yucca Mountain.

Use. Two wells, J-12 and J-13 (shown in Figure 3-20), are part of the water system for site characterization activities at Yucca Mountain. These are the nearest production wells to Yucca Mountain and they support water needs for Area 25 of the Nevada Test Site and for Exploratory Studies Facility activities. Both of these wells withdraw groundwater from the Jackass Flats hydrographic area, as listed in Table 3-11. Groundwater has also been pumped from the Jackass Flats area from various boreholes for hydraulic testing, and most recently from the C-well complex, which consists of three separate wells grouped in an area just east of the South Portal Development Area (DIRS 100465-Luckey et al. 1996, Figure 17). In addition, water has been pumped occasionally from borehole USW VH-1 (also designated CF-2) in support of Yucca Mountain characterization activities. But the volume pumped from this well, which is in the Crater Flat hydrographic area, is small (DIRS 100465-Luckey et al. 1996, p. 70).

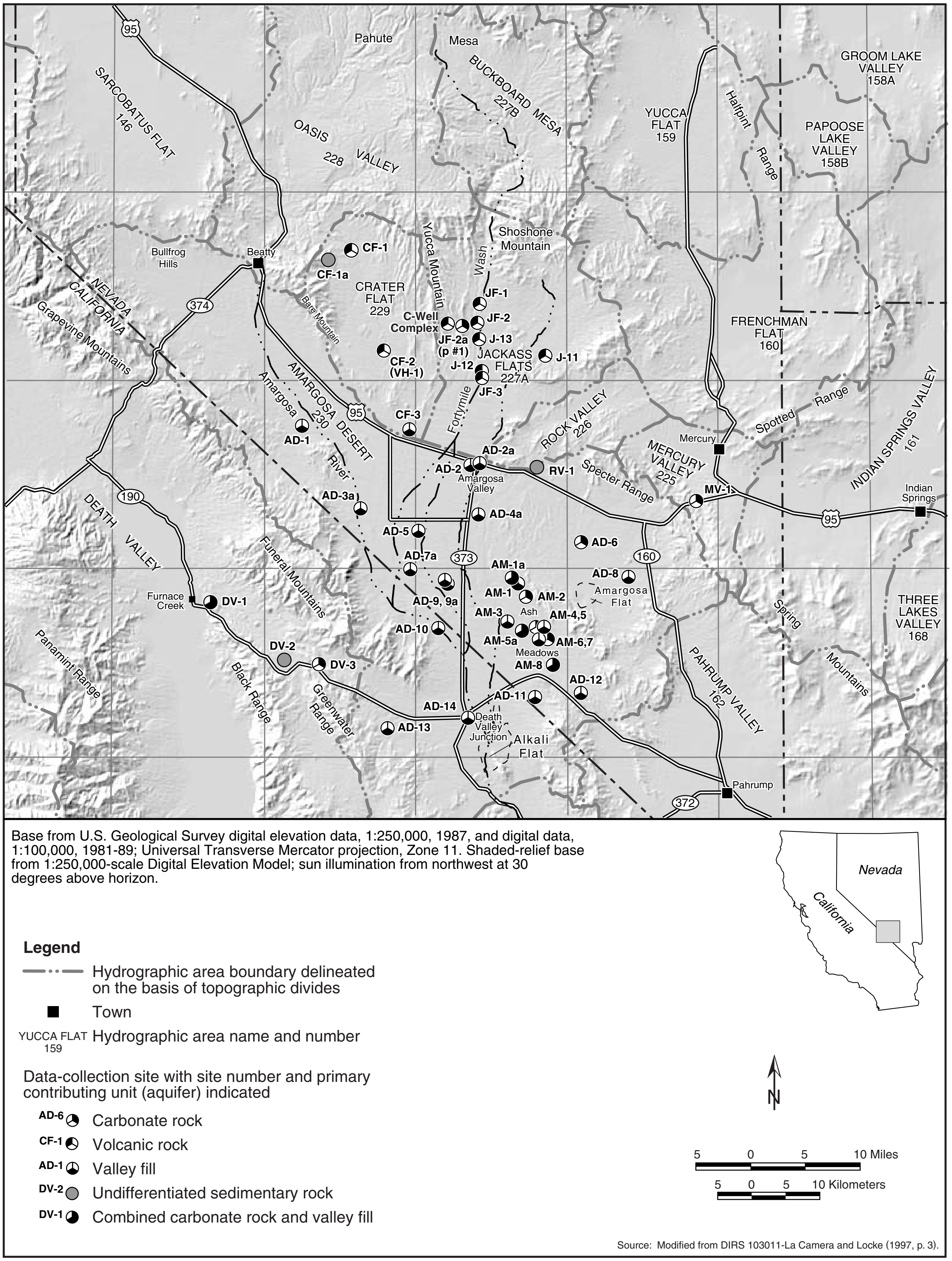

Figure 3-20. Selected groundwater data-collection sites in the Yucca Mountain region.

The Yucca Mountain Site Characterization Project has received water appropriation permits (Numbers 57373, 57374, 57375, and 57376) from the State of Nevada for wells J-12, J-13, VH-1 (also known as CF-2), and the C-Well complex (Numbers 58827, 58828, and 58829), and a Potable Water Supply permit (NY-0867-12NCNT) for the distribution system. The permits allow a maximum pumping rate of about 0.028 cubic meter (1 cubic foot) a second, with a maximum yearly withdrawal of about 530,000 cubic meters (430 acre-feet) (DIRS 151945-CRWMS M&O 2000, p. 9.5-3 and 9.5-4, and Table 9.5-3, p. T9.5-3). The permit limits apply to site characterization water use. Table 3-16 lists historic and projected water use from wells J-12 and J-13 from 1992 to 2005 for the Exploratory Studies Facility and Concrete Batch Plant, and from the C-Wells, which is pumped and then reinjected as part of aquifer testing. It also lists the total amount of water pumped from wells J-12 and J-13 for both Yucca Mountain and the Nevada Test Site. The difference between the quantities pumped from wells J-12 and J-13 for Yucca Mountain activities and the total withdrawals from these wells represents the quantities used for Nevada Test Site activities in the area. The water-use projections in Table 3-16 are through the end of site characterization activities; Section 4.1.3 discusses water demand projections for the proposed repository.

Table 3-16. Water withdrawals (acre-feet)[a] from wells in the Yucca Mountain vicinity.

Year	J-12 and J-13 Yucca Mountain characterization[b]	J-12 and J-13 total withdrawals[c]	C-wells[b]
1992	18	120	0
1993	80	210	0
1994	75	280	0
1995	94	260	19
1996	66	220	180
1997	63	150	190
1998	63[d]	N/A[e]	190[f]
1999	63	N/A	N/A
2005	63	N/A	N/A

a. To convert acre-feet to cubic meters, multiply by 1233.49.
b. Source: DIRS 104988-CRWMS M&O (1999, p. 4).
c. Source: DIRS 103171-Clary et al. (1995, p. 660); DIRS 101486-Bauer et al. (1996, p. 702); DIRS 103090-Bostic et al. (1997, p. 592); DIRS 103082-Bonner et al. (1998, p. 606); DIRS 103283-La Camera, Locke, and Munson (1999, all); withdrawals for 1992 and 1993 were estimated from figures in DIRS 103011-La Camera and Locke (1997, p. 51).
d. Assumed to remain constant from 1997 through 2005.
e. N/A = not available.
f. Assumed to remain constant from 1997 to 1998.

The U.S. Geological Survey, in support of Yucca Mountain characterization efforts and in compliance with the State permits, has kept records of the amount of water pumped from the J-12 and J-13 wells and of measured water elevation levels in those and other wells in their immediate area since 1992 (DIRS 103011-La Camera and Locke 1997, pp. 1 and 2). One of the objectives of keeping these records is to detect and document changes in groundwater resources during the Yucca Mountain investigations. Therefore, the Survey effort included the collection of historic water elevation data to establish a baseline. Results from these efforts have been documented in annual reports. The report for 1997 (DIRS 103283-La Camera, Locke, and Munson 1999, all) includes a summary of 1996 results and detailed results for 1997. Table 3-17 summarizes the changes observed in median groundwater elevations in seven wells in Jackass Flats. The second column of the table identifies the historic or baseline elevation for each well against which the annual median values are being compared. In addition, the table lists the average deviation of measured water levels during the period from which the baseline was generated.

Table 3-17. Differences between annual median elevations and baseline median elevations.[a]

Well	Baseline elevations: Median (meters[c] above sea level)	Baseline elevations: Average deviation about the median (centimeters)	Difference (in centimeters[b]) baseline: 1992	1993	1994	1995	1996	1997
JF-1	729.23	± 6	–3	0	–6	0	–6	–3
JF-2	729.11	± 9	+3	0	+3	+9	0	–3
JF-2a[d]	752.43	± 12	0	+6	+12	+15	+21	+27
J-13	728.47	± 6	–3	–3	–9	–6	–12	–12
J-11	732.19	± 3	0	0	+3	+6	+6	+12
J-12	727.95	± 3	0	0	–3	–3	–9	–9
JF-3	727.95	± 3	N/A[e]	N/A	–6	–6	–9	–9

a. Source: DIRS 103283-La Camera, Locke, and Munson (1999, Table 10).
b. To convert centimeters to inches, multiply by 0.3937.
c. To convert meters to feet, multiply by 3.2808.
d. Well JF-2a is also known as UE-25 p#1, or P-1.
e. N/A = not available.

The elevation changes listed in Table 3-17 are different from the short-term fluctuations described above that are a response to changes in barometric pressure and Earth tides. The differences in comparison of annual median values should indicate water level trends, if there are any. The data show that a decline in groundwater elevation has been seen in some, but not all, of the local wells. Specifically, the data show the following:

- Two wells, JF-1 and JF-2, stayed within the band of elevations characteristic of the baseline data.
- Two wells, JF-2a (also known as UE-25 p#1, or P-1) and J-11, indicated elevation increases of 15 and 9 centimeters (about 5.9 and 3.5 inches), respectively, above the band of elevations characteristic of the baseline data (and even higher above the median of the baseline data as listed in the table).
- Three wells, J-13, J-12, and JF-3, each indicated an elevation decrease of 6 centimeters (about 2.4 inches) below the band of elevations characteristic of the baseline data (and even further below the median of the baseline data as listed in the table).

In its discussion of groundwater levels, the U.S. Geological Survey (DIRS 103011-La Camera and Locke 1997, p. 22) indicated that monitoring of water levels in the seven wells should continue to see if additional decreases occur and if they can be correlated to periods of withdrawal. In regard to overall groundwater levels in the Jackass Flats area, the data do not appear to show any definitive trend in elevation change, either up or down. However, the three wells showing a water decline are either being pumped (J-12 and J-13) or, in the case of JF-3, are close to a production well. Of the two wells (JF-2a and J-11) showing water-level increases, one (JF-2a) penetrates the lower carbonate aquifer and the other, though penetrating a volcanic aquifer, is farthest from the production wells of any shown on the table. Pumping from the volcanic aquifer production wells would be unlikely to affect either of these wells. There is some speculation that the consistent water-level increase over time in well JF-2a might indicate that it has not yet reached an *equilibrium* elevation.

Saturated Zone Groundwater Quality. Groundwater quality for the aquifers beneath Yucca Mountain was addressed by the Geological Survey sampling and analysis effort described above for regional groundwater quality. This effort included the collection and analysis of samples from three wells in the Jackass Flats area (including J-12 and J-13); the results indicated that the concentrations of dissolved substances in local groundwater were below the numerical criteria of the primary drinking water standards set by the Environmental Protection Agency for public drinking water systems (DIRS 104828-Covay 1997, all). However, samples from each of the wells exceeded the secondary standard for fluoride,

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as they did for a proposed standard for radon. Both of these constituents occur naturally in the rock through which the groundwater flows. Overall, local groundwater quality is generally good.

Investigations of the chemical and mineral composition of groundwater at Yucca Mountain have provided an indication of the differences between the aquifers beneath the site. The chemical composition of groundwater depends on the chemistry of the recharge water and the chemistry of the rocks through which the water travels. Water in the volcanic aquifers and confining units at Yucca Mountain has a relatively dilute sodium-potassium-bicarbonate composition that probably results from the *dissolution* of volcanic tuff (Table 3-18). The chemistry of water from the lower carbonate aquifer is very different (a generally more concentrated calcium-magnesium-bicarbonate composition), which would be expected from water traveling through and dissolving carbonate rock (Table 3-18).

Table 3-18. Water chemistry of volcanic and carbonate aquifers at Yucca Mountain (milligrams per liter).[a]

Chemical constituent	Chemical composition: Volcanic aquifers[b]	Chemical composition: Lower carbonate aquifer[c]
Calcium	1.4 - 37	100
Magnesium	< 0.01 - 10	39
Potassium	1.1 - 5.6	12
Sodium	38 - 120	150
Bicarbonate	110 - 282	569
Chloride	5.5 - 13	28
Sulfate	16 - 45	160
Silica	40 - 57	41

a. Source: DIRS 101036-Benson and McKinley (1985, Table 1, p. 5).
b. Based on samples from 14 wells.
c. Based on samples from one well.

As part of the Yucca Mountain project, well and spring monitoring activities performed during 1997 aided the establishment of a baseline for radioactivity in groundwater near the site of the proposed repository (DIRS 104963-CRWMS M&O 1998, all). The quarterly sampling included six wells and two springs that were selected to ensure that at least two were representative of each of the three general aquifers (carbonate, volcanic, and alluvial) in the region. Samples were analyzed for gross alpha, gross beta, total uranium, and concentrations of selected beta and gamma-emitting radionuclides. Table 3-19 lists the results from this monitoring as average values from the quarterly sampling events for each well or spring. The table lists the location of each well or spring, including the data collection site designations shown on Figure 3-20, the contributing aquifer, and a comparison, if applicable, to *Maximum Contaminant Levels* established by the Environmental Protection Agency for water supplied by public drinking water systems. As indicated in the table, the sites sampled include locations outside the Alkali Flat-Furnace Creek groundwater basin in which Yucca Mountain is located. The Cherry Patch location is in the Ash Meadows groundwater basin and Crystal Pool and Fairbanks Spring are on the border between the two basins, but are fed by flow through Ash Meadows. The location variety supports area comparisons as well as comparisons between the different contributing aquifers.

Table 3-19 indicates that Maximum Contaminant Levels for combined radium-226 and radium-228 and for gross alpha were not exceeded by the average values from any of the sampling sites or by the maximum values reported for those parameters (DIRS 104963-CRWMS M&O 1998, pp. 12 to 21). The samples were analyzed for other beta- or gamma-emitting radionuclides, specifically tritium, carbon-14, chlorine-36, nickel-59, strontium-89, strontium-90, technetium-99, iodine-129, and cesium-137. The table does not list the results for these parameters because they are below minimum detectable activity (DIRS 104963-CRWMS M&O 1998, p. 13). As a conservative measure, however, DOE used the values reported by the laboratory to calculate dose contributions (DIRS 104963-CRWMS M&O 1998, Appendix F). Water from each sampling location was shown to have exposure values well below the 4-millirem-per-year total body (or any internal organ) dose limit set as the Maximum Contaminant Level for beta- or gamma-emitting radionuclides.

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Table 3-19. Results of 1997 groundwater sampling and analysis for radioactivity.[a]

Site name and location description[b]	Contributing aquifer	Average combined radium-226 and -228 (picocuries per liter)	Average gross alpha (picocuries per liter)	Average total uranium[c] (micrograms per liter)	Average gross beta (picocuries per liter)	Average radon-222 (picocuries per liter)
J-12 and J-13[d] Fortymile Wash, SE of Yucca Mtn.	Volcanic	0.32±0.24	BDL[e]	0.52±0.03	6.04±0.60	384
C-3 (C-well complex) By South Portal, SE of Yucca Mtn.	Volcanic	0.58±0.36	1.34±1.05	1.04±0.09	3.59±0.76	763
Crystal Pool (Spring) (AM-5a) Ash Meadows	Carbonate/ alluvial[f]	0.93±0.20	BDL	2.64±0.23	14.0±1.28	447
Fairbanks Spring (AM-1a) Ash Meadows	Carbonate/ alluvial	0.80±0.36	BDL	2.23±0.19	11.1±1.17	279
Nevada Department of Transportation Well (AD-2a) Amargosa Valley	Alluvial	0.32±0.33	BDL	2.55±0.22	5.95±0.93	612
Gilgans South Well (AD-9a) Amargosa Desert	Alluvial	0.19±0.31	BDL	0.63 ± 0.05	9.14±0.97	600
Cherry Patch Well (AD-8) NE of Ash Meadows	Alluvial	0.22±0.33	9.19±4.35	13.1 ± 1.16	18.7±1.65	504
Drinking water Maximum Contaminant Levels[g]		5	15	NA[h]	NA	300 (proposed)

a. Source: DIRS 104963-CRWMS M&O 1998, pp. 12 to 21) for all but radon-222 data; DIRS 104828-Covay (1997, Table 4) for radon data.
b. Figure 3-20 shows the locations of the wells.
c. To convert total uranium concentrations in micrograms per liter to picocuries per liter, multiply by 0.68 (DIRS 104963-CRWMS M&O 1998, p. 15).
d. Average of data presented for Well J-12 and Well J-13.
e. BDL = below detection limit.
f. Alluvium is also identified as valley fill in DIRS 151945-CRWMS M&O (2000, p. 9.2-23).
g. Drinking water Maximum Contaminant Levels are set by the Environmental Protection Agency in 40 CFR Part 141.
h. NA = not applicable.

There is no indication that DOE activities at the Nevada Test Site have contaminated the groundwater beneath Yucca Mountain. This is consistent with studies performed on the Nevada Test Site. DIRS 103411-Nimz and Thompson (1992, all) documented about a dozen instances in which radionuclides have migrated into the groundwater from areas of nuclear weapons testing at the Nevada Test Site in 40 years. The maximum distance of tritium migration is believed to be several kilometers; less mobile radioactive constituents, which include a wide variety of isotopes (DIRS 101811-DOE 1996, pp. 4-126 to 4-129), have migrated no more than about 500 meters (1,600 feet). There has, however, been recent evidence of plutonium migration from one below-groundwater test at Pahute Mesa.

Groundwater monitoring results indicate plutonium has migrated at least 1.3 kilometers (0.8 mile) from this site in 28 years and is apparently associated with the movement of very small particles called colloids (DIRS 103282-Kersting et al. 1999, p. 56). None of the nuclear testing occurred in Area 25 where the Yucca Mountain Repository facilities would be. However, the flow of groundwater from areas on Pahute and Buckboard Mesas where DOE conducted 81 and 2 nuclear tests, respectively, could be to the south toward Yucca Mountain. The distance is about 40 kilometers (25 miles) to Pahute Mesa and about 30 kilometers (19 miles) to Buckboard Mesa (Figure 3-20). Because of these distances, there is no reason to believe that radionuclides from nuclear tests could migrate as far as Yucca Mountain during the active life (construction, operation and monitoring, and closure phases) of the repository, with the possible exception of tritium. Conservative modeling performed by DOE at the Nevada Test Site (DIRS 103021-DOE 1997, pp. ES-27 to ES-29, and ES-36) shows that tritium, moving with little or no attenuation in groundwater other than decay, could move to locations at or near Nevada Test Site boundaries in tens of years. However, the same study reports that monitoring has not shown tritium to be moving as rapidly as predicted when using the conservative assumptions of the model. In addition, the flow paths from the underground nuclear testing areas, as predicted in this study, do not intersect groundwater beneath Yucca Mountain. Chapter 8 discusses the potential for long-term migrations of radionuclides to result in cumulative radiation from nuclear testing contamination eventually migrating through the groundwater system and joining groundwater beneath the repository.

3.1.5 BIOLOGICAL RESOURCES AND SOILS

The region of influence for biological resources and soils is the area that contains all potential surface disturbances that would result from the Proposed Action plus some additional area to evaluate local animal populations. This region is roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (230 square miles). DOE used available information and studies on plants and animals at the site of the proposed repository and the surrounding region to identify baseline conditions for biological resources. This information included land cover types, vegetation associations, and the distribution and abundance of plant and animal species in the region of influence (the analyzed land withdrawal area) and in the broader region. The plants and animals in the Yucca Mountain region are typical of species in the Mojave and Great Basin Deserts.

DOE has surveyed the region for naturally occurring wetlands and has studied soil characteristics (thicknesses, water-holding capacity, texture, and erosion hazard) in the region. This section summarizes this information and describes existing soil conditions in relation to potential contaminants. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, all) or the *Environmental Baseline File for Soils* (DIRS 104592-CRWMS M&O 1999, all).

The State of Nevada (DIRS 148188-Loux 1997, all) expressed the view that there was no systematic integrated environmental program to characterize the unique and fragile desert environment at Yucca Mountain before 1982, when DOE began site investigation that may have caused irreversible alterations (DIRS 103298-Lemons and Malone 1989, pp. 435 to 441). However, the State acknowledged that after site investigations started and impacts might have occurred, DOE began studies of sensitive species, archaeology, airborne particulates, and groundwater (DIRS 103298-Lemons and Malone 1989, pp. 435 to 441), and established an environmental baseline from these data (DIRS 103396-Malone 1989, pp. 77 to 95). DIRS 103398-Malone (1995, pp. 271 to 284) contended that many of the studies conducted to establish the baseline and evaluate impacts, particularly those on plants and animals, were not adequately designed and did not use an integrated ecosystem approach and, therefore, were of little value for evaluating impacts of the repository.

DOE contends that studies initiated after the start of site investigations are suitable for establishing the baseline needed for this EIS. The purpose of studies of the impacts of site characterization activities on plants and animals was not to evaluate potential impacts from a repository, but rather to focus on the appropriate level of ecological organization for the types of impacts that occurred during characterization activities. DOE used the results of those studies in the EIS analysis to understand and predict possible impacts from similar activities that would occur during repository construction and operation (for example, habitat destruction).

3.1.5.1 Biological Resources

3.1.5.1.1 *Vegetation*

DOE adapted broad categories of land cover types for the analyzed land withdrawal area (based primarily on predominant vegetation; see Figure 3-21) from two sources: a statewide classification and a detailed, field-validated classification of the area surrounding the location of the proposed repository. Land cover types typical of the Mojave and Great Basin Deserts occur in the analyzed land withdrawal area; they include creosote-bursage (56 percent), blackbrush (14 percent), hopsage (13 percent), Mojave mixed scrub (10 percent), salt desert scrub (4 percent), sagebrush (3 percent), and pinyon-juniper (much less than 1 percent). None of the more than 210 plant species known to occur in the analyzed land withdrawal area is endemic to the area; that is, they all occur in other places.

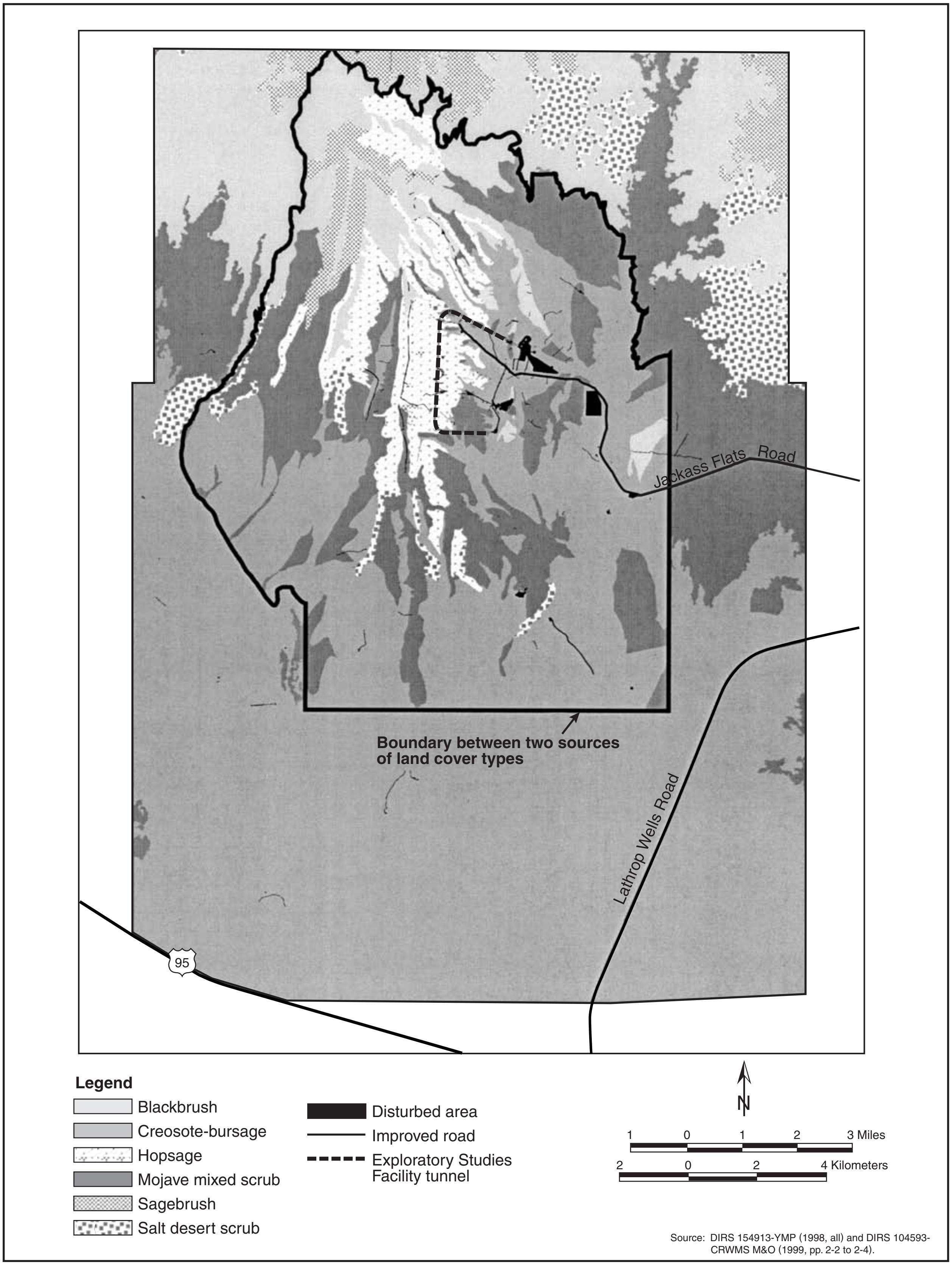

Figure 3-21. Land cover types in the analyzed land withdrawal area.

Plant species typical of the Mojave Desert dominate the vegetation at low elevations in the analyzed land withdrawal area. Low-elevation valleys, alluvial fans, and large washes are dominated by white bursage (*Ambrosia dumosa*), creosotebush (*Larrea tridentata*), Nevada jointfir (*Ephedra nevadensis*), littleleaf ratany (*Krameria erecta*), and pale wolfberry (*Lycium pallidum*). Low-elevation hillsides are dominated by similar species, with the addition of shadscale (*Atriplex confertifolia*), California buckwheat (*Eriogonum fasciculatum*), and spiny hopsage (*Grayia spinosa*).

At higher elevations, generally at the northern end of the analyzed land withdrawal area, species typical of the Great Basin Desert are dominant. Ridge tops and slopes are dominated by blackbrush (*Coleogyne ramosissima*), heathgoldenrod (*Ericameria teretifolius*), Nevada jointfir, broom snakeweed (*Gutierrezia sarothrae*), green ephedra (*Ephedra viridis*), and California buckwheat. On some steep north-facing slopes, big sagebrush (*Artemisia tridentata*) is predominant.

There are approximately 30 exotic plant species present in the Yucca Mountain area. The most common species include red brome (*Bromus rubens*), Russian thistle (*Salsola* spp.), tumble mustard (*Sisymbrium altissimum*), halogeton (*Halogeton glomeratus*), and Arabian schismus (*Schismis arabicus*). Red brome is the most abundant exotic species in the area. None of these exotic species is on the State of Nevada's Noxious Weed List (DIRS 155925-NWAC 2000, Appendix A).

3.1.5.1.2 *Wildlife*

Wildlife at Yucca Mountain is dominated by species associated with the Mojave Desert, with some species from the Great Basin Desert at higher elevations.

The 36 species of mammals that have been observed in the analyzed Yucca Mountain land withdrawal area include 17 species of rodents, seven species of bats, three species of rabbits and hares, and nine species of large mammals such as coyote *(Canis latrans)*, mule deer *(Odocoileus hemionus)*, and burros (*Equus asinus*). The most abundant species are long-tailed pocket mice *(Chaetodipus formosus*) and Merriam's kangaroo rats (*Dipodomys merriami*).

The 27 species of reptiles include 12 species of lizards, 14 species of snakes, and the desert tortoise (*Gopherus agassizii*). The most abundant lizard is the side-blotched lizard (*Uta stansburiana*), while the western whiptail (*Cnemidophorus tigris*) is common. The most abundant snakes are the coachwhip (*Masticophis flagellum*) and the long-nosed snake (*Rhinocheilus lecontei*). No amphibians have been found at Yucca Mountain.

There have been no formal attempts to quantify the birds present at Yucca Mountain, but at least 120 species have been sighted in or near the analyzed land withdrawal area, including 14 species that nest there. Transient and resident species have been recorded including species typical of the desert, migrating water birds and warblers, and raptors. Black-throated sparrows (*Amphispiza bilineata*) are the most common resident birds and mourning doves (*Zenaida macroura*) are seasonally common.

Researchers have collected invertebrates from 18 orders and 53 families at Yucca Mountain. Members of the insect orders Lepidoptera (butterflies and moths), Hymenoptera (bees, wasps, and ants), and Coleoptera (beetles) were the most numerous of those collected.

Several game species and furbearers (see Nevada Administrative Code 503.125) have been observed in the analyzed land withdrawal area, including (1) three species of game birds—Gambel's quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), and mourning doves, (2) mule deer (*Odocoileus hemionus*), and (3) three species of furbearers—kit foxes (*Vulpes velox*), mountain lions (*Puma concolor*), and bobcats (*Lynx rufus*).

3.1.5.1.3 *Special Status Species*

No plant species listed as threatened or endangered or that are proposed or candidates for listing under the Endangered Species Act occur in the analyzed land withdrawal area. No plant species classified as sensitive by the Bureau of Land Management are known to occur in the analyzed land withdrawal area. Several species of cacti and yucca, all of which are protected by the State of Nevada from commercial collection, are scattered throughout the region, including the analyzed land withdrawal area.

SPECIAL STATUS SPECIES

An **endangered species** is classified under the Endangered Species Act as being in danger of extinction throughout all or a significant part of its range.

A **threatened species** is classified under the Endangered Species Act as likely to become an endangered species in the foreseeable future.

Candidate species are species for which the Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

The State of Nevada has also designated special status species as endangered, threatened, protected, and sensitive. Species with these classifications are protected under Nevada Administrative Code Chapter 503.

Bureau of Land Management **sensitive species** include species designated by the Bureau's State Director in addition to those listed, proposed, or candidates under the Endangered Species Act or listed by the State of Nevada as endangered or otherwise protected.

One animal species that occurs at Yucca Mountain, the desert tortoise, is listed as threatened under the Endangered Species Act. Yucca Mountain is at the northern edge of the range of the desert tortoise (DIRS 101915-Rautenstrauch, Brown, and Goodwin 1994, p. 11), and the abundance of tortoises at Yucca Mountain is low or very low in comparison to other portions of its range. Aspects of the ecology of the desert tortoise population at Yucca Mountain have been studied extensively (DIRS 104593-CRWMS M&O 1999, all).

Individual bald eagles (*Haliaeetus leucocephalus)* and peregrine falcons (*Falco peregrinus)* occasionally migrate through the region; these species have been seen once each at the Nevada Test Site. Both species are rare in the region and have not been seen at Yucca Mountain. Bald eagles are classified as threatened under the Endangered Species Act, and the State of Nevada classifies both birds as endangered.

No other Federally listed threatened or *endangered species* or candidates for listing under the Endangered Species Act occur at Yucca Mountain.

Five species classified as sensitive by the Bureau of Land Management occur at Yucca Mountain. Two species of bats—the long-legged myotis (*Myotis volans*) and the fringed myotis (*M. thysanodes*)—have been observed near the site. Three other species, the western chuckwalla (*Sauromalus obesus*), burrowing owl (*Speotyto cunicularia*), and Giuliani's dune scarab beetle (*Pseudocotalpa giulianii*), occur in the analyzed land withdrawal area. The chuckwalla, one of the largest lizards in Nevada, is locally common and widely distributed in rocky habitats throughout the analyzed land withdrawal area and the surrounding region. The seldom-seen burrowing owl generally occurs in valley bottoms and is known to be a year-round resident at the Nevada Test Site. Giuliani's dune scarab beetle has been found near the cinder cones north of U.S. Highway 95 at the south end of Crater Flat.

Ash Meadows National Wildlife Refuge and Devils Hole (which is administered as part of Death Valley National Park) are about 39 kilometers (24 miles) south of Yucca Mountain. Although Ash Meadows and Devils Hole are outside the region of influence for biological resources, they contain a number of special status species that an evaluation of regional biological resources should consider. Of the eight endemic plant species at Ash Meadows, one is listed as endangered (Amargosa alkali plant, *Nitrophila mohavensis*) and six are listed as threatened (Spring-loving centaury, *Centaurium namophilum*; Ash Meadows milkvetch, *Astragalus phoenix*; Ash Meadows naked stem sunray, *Enceliopsis nudicaulis* var. *corrugata*; Kings Mousetail, *Ivesia kingii* var. *eremica*; Ash Meadows gumweed, *Grindelia fraximopratensis*; and Ash Meadows blazing star, *Mentzelia leucophylla*) (50 *FR* 20777, May 20, 1985). Four endemic fish species occur in the springs and pools. The Fish and Wildlife Service and the State of Nevada list these species—the Ash Meadows Amargosa speckled dace (*Rhinichthys osculus nevadensis*), Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*), Devils Hole pupfish (*C. diabolis*), and Warm Springs Amargosa pupfish (*C. nevadensis pectoralis*)—as endangered. The springs also provide habitat for a number of endemic riffle beetles, springsnails, and other invertebrates, including the threatened Ash Meadows naucorid bug (*Ambrysus amargosus*).

3.1.5.1.4 *Wetlands*

There are no naturally occurring jurisdictional wetlands (wetlands that are regulated under Section 404 of the Clean Water Act) at Yucca Mountain. Four manmade ponds in the Yucca Mountain region have *riparian* vegetation. Fortymile Wash and some of its tributaries might be classified as waters of the United States as defined by the Clean Water Act. Jurisdictional wetlands associated with Ash Meadows are outside the region of influence for the Proposed Action.

3.1.5.2 Soils

Researchers have conducted a soil survey centered on Midway Valley (the location of the proposed North Portal facilities) and the ridges to the west (DIRS 103450-Resource Concepts 1989, all), and a more general soil survey of the entire Yucca Mountain region (DIRS 104851-YMP 1997, all). The survey that centered on Midway Valley identified 17 soil series and seven map units (Table 3-20) at Yucca Mountain (DIRS 103450-Resource Concepts 1989, all); none of these series is classified as *prime farmland*. Based on a wetlands assessment at the Nevada Test Site (DIRS 101833-Hansen et al. 1997, all), there are no hydric soils at Yucca Mountain. Yucca Mountain soils are derived from underlying volcanic rocks and mixed alluvium dominated by volcanic material, and in general have low water-holding capacities.

The shallow soils on ridge tops at Yucca Mountain often consist of a thin *hardpan* (hardened or cemented soil layer) on top of bedrock and range from *well drained* to

SOIL TERMS

Prime farmland: Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not included). It has the soil quality, growing season, and moisture supply needed for the economic production of sustained high yields of crops when treated and managed (including water management) according to acceptable farming methods (Farmland Protection Policy Act of 1981, 7 CFR 7.658).

Piedmont: Land lying along or near the foot of a mountain. For example, a fan piedmont is a fan-shaped landform between the mountain and the basin floor.

Table 3-20. Soil mapping units at Yucca Mountain.[a]

Map unit	Percent	Geographic setting	Soil characteristics
Upspring-Zalda	11	Mountain tops and ridges. Soils occur on smooth, gently sloping ridge tops and shoulders and on nearly flat mesa tops. Rhyolite and tuffs are parent materials for both soil types.	Typically shallow (10 - 51 cm[b]) to bedrock, or to thin duripan[c] over bedrock. They are well to excessively drained, have low available water-holding capacity, medium to rapid runoff potential, and slight erosion hazard.
Gabbvally-Downeyville-Talus	8	North-facing mountain sideslopes. Talus is stone-sized rock occurring randomly throughout unit in long, narrow, vertically oriented accumulations.	Shallow (10 - 36 cm) to bedrock. Permeability is moderate to moderately rapid. They have moderate to rapid runoff potential, are well drained, and have low available water-holding capacity and moderate erosion hazard.
Upspring-Zalda-Longjim	27	Mountain sideslopes. Soils occur on south-, east-, and west-facing slopes, and on moderately sloping alluvial deposits below sideslopes.	Shallow (10 - 51 cm) to bedrock or to thin duripan over bedrock. They are well to excessively drained and have moderately rapid to rapid permeability and runoff potential, very low available water-holding capacity, and slight erosion hazard.
Skelon-Aymate	22	Alluvial fan remnants. Soils occur on gently to strongly sloping summits and upper sideslopes.	Moderately deep (51 - 102 cm) to indurated[d] duripan or petrocalcic[e] layer with low to very low available water-holding capacity, moderately rapid permeability, slow runoff potential, and slight erosion hazard.
Strozi variant-Yermo-Bullfor	7	Alluvial fan remnants. Soils occur on gently to moderately sloping alluvial fan remnants and stream terraces adjacent to large drainages.	Moderately deep (51 - 102 cm) to deep (102 cm). They are well drained and have rapid permeability, very low available water-holding capacity, slow runoff potential, and slight erosion hazard.
Jonnic variant-Strozi-Arizo	12	Dissected alluvial fan remnants. Soils occur on fan summits, moderately sloping fan sideslopes, and inset fans. They are formed in alluvium from mixed volcanic sources.	Moderately deep (36 - 43 cm) to deep (more than 102 cm), sometimes over strongly cemented duripan. They have slow or rapid permeability, slow or moderate runoff potential, very low available water-holding capacity, and slight erosion hazard.
Yermo-Arizo-Pinez	13	Inset fans and low alluvial sideslopes in mountain canyons; and drainages between fan remnants. Soils occur on moderately to strongly sloping inset fans near drainages, adjacent to lower fan remnants, and below foothills.	Deep (more than 102 cm), sometimes over indurated duripan. They are well drained and have very low available water holding-capacity, moderately slow to rapid permeability, slow to medium runoff potential, and slight erosion hazard.

a. Source: DIRS 104592-CRWMS M&O (1999, pp. 3 and 4).
b. To convert centimeters (cm) to inches, multiply by 0.3937.
c. Duripan: A subsurface layer cemented by silica, usually containing other accessory cements.
d. Indurated: Hardened, as in a subsurface layer that has become hardened.
e. Petrocalcic: A subsurface layer in which calcium carbonate or other carbonates have accumulated to the extent that the layer is cemented or indurated.

excessively drained, which means that water drains readily to very rapidly. The soil has a topsoil layer typically less than 15 centimeters (6 inches) thick and, in some instances, a subsoil layer 5 to 30 centimeters (2 to 12 inches) thick. Soil textures range from gravelly to cobbly, loamy sands to sandy loams. Soils are calcareous (high in calcium carbonate), with lime coatings on the undersides of rocks in the subsoil layer. The soils are moderately to strongly alkaline, with a *pH* ranging from 8.0 to 8.6. Rock fragments ranging in size from gravel to cobbles dominate 45 to 65 percent of the ground surface.

Soils on fan piedmonts and in steep, narrow canyons are relatively deep and are *well drained* (water is drained readily, but not rapidly). These soils developed from residues of volcanic parent material, with a component of calcareous eolian sand. Soils formed from the volcanic parent material generally range from *moderately shallow* [50 to 75 centimeters (20 to 30 inches)] to *moderately deep* [75 to 100 centimeters (30 to 40 inches)] over a thin hardpan on top of bedrock. The topsoil layers are generally less than 25 centimeters (10 inches) thick, with a subsoil layer thickness of 25 to 50 centimeters (10 to 20 inches). The mixed soils, containing residues from volcanic parent material and calcareous eolian sand, are often *deep* [100 to 150 centimeters (40 to 60 inches)] or moderately deep, having a well-cemented hardpan. The topsoil layers are less than 15 centimeters (6 inches) thick, with the layer of soil parent material as deep as 150 centimeters (60 inches). Soil textures are gravelly, sandy loams with 35 to 70 percent rock fragments. Soils are generally calcareous and moderately to strongly alkaline.

Soils on alluvial fans and in stream channels are *very deep* [greater than 150 centimeters (60 inches)] and range from well drained to excessively drained. The topsoil layers are generally less than 20 centimeters (8 inches) thick, with the layer of soil parent material as deep as 150 centimeters. Soil textures are very gravelly, with fine sands to sandy loams and abundant rock fragments. The soils are calcareous and moderately alkaline.

The Yucca Mountain site characterization project has sampled and analyzed surface soils for radiological constituents. In addition, records of spills or releases of nonradioactive materials have been maintained to meet regulatory requirements and to provide a baseline for the Proposed Action. A recent summary of existing radiological conditions in soils is based on 98 surface samples collected within 16 kilometers (10 miles) of the Exploratory Studies Facility. The results of that analysis, when compared to other parts of the world, indicate average levels of the naturally occurring radionuclide uranium-238 series decay products and above-average levels of the naturally occurring radionuclides potassium-40 and thorium-232 series decay products. The higher-than-average radionuclide values might be due to the origin of the soil at the site from tuffaceous igneous rocks. The studies also detected concentrations of the manmade radionuclides strontium-90, cesium-137, and plutonium-239 from worldwide nuclear weapons testing.

3.1.6 CULTURAL RESOURCES

Cultural resources include any prehistoric or historic district, site, building, structure, or object resulting from or modified by human activity. Cultural resources could also include potential *traditional cultural properties*. Under Federal regulation, cultural resources designated as historic properties warrant consideration with regard to potential adverse impacts resulting from proposed Federal actions. A cultural resource is an historic property if its attributes make it eligible for listing or it is formally listed on the *National Register of Historic Places*. For this analysis, DOE has

CULTURAL RESOURCES

Archaeological site: The location of a past event, a prehistoric or historic occupation or activity, or a building or structure, whether standing, ruined, or vanished, where the location itself maintains archaeological value.

Traditional cultural property: A property associated with the cultural practices or beliefs of a living community that are (1) rooted in that community's history, and (2) important in maintaining the cultural identity of the community.

evaluated the importance of historic and archaeological resources according to National Register eligibility criteria.

Cultural resources at Yucca Mountain include archaeological resources that are prehistoric or historic, and other resources important to Native American tribes and organizations, such as potential traditional cultural properties. The region of influence for cultural resources includes the land areas that would be disturbed by the proposed repository activities (as described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur. DOE has collected information on the various types of archaeological sites, detailing their purposes and the kinds of artifacts typically present. DOE also has focused on Native American interests in the region's cultural resources. Section 3.1.6.2 summarizes these issues in discussions of Native American views of the affected environment.

Unless otherwise indicated, the information in this section is derived from either the summary of past archaeological projects at Yucca Mountain (DIRS 104997-CRWMS M&O 1999, all) or from *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all).

3.1.6.1 Archaeological and Historic Resources

Site characterization efforts have led to a number of archaeological investigations at Yucca Mountain over the past two decades, including, as an early action, an archaeological field survey of a 44-square-kilometer (about 11,000-acre) parcel that proposed repository activities probably would affect. The field survey was followed by limited test excavations at 29 sites to determine their scientific importance and to develop management strategies for the protection of archaeological resources. Additional archaeological surveys have been conducted along nearby Midway Valley and Yucca Wash, in lower Fortymile Canyon just east of the Yucca Mountain site, and around Dune Wash east of southern Yucca Mountain.

Concurrent with these investigations, DOE directed archaeological surveys and data-recovery projects before beginning planned ground-disturbing activities specific to the Yucca Mountain Project. Limited data-recovery efforts at 18 archaeological sites support a model for a local cultural sequence that includes a pattern of linear-shaped sites along major drainages dating as far back as 7,000 years, and a shift to a more dispersed pattern of sites about 1,500 years ago. A site monitoring program designed to examine human and natural impacts to cultural resources through time began in 1991 and is continuing at Yucca Mountain.

Decades of cultural resource investigations at Yucca Mountain and at the Nevada Test Site have revealed archaeological features and artifacts. Based on archaeological site file searches at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, approximately 830 archaeological sites have been discovered in the analyzed land withdrawal area. Most of the known archaeological sites are small scatters of lithic (stone) artifacts, usually comprised of fewer than 50 artifacts with few formal tools and no temporally or culturally diagnostic artifacts in the inventory. None of the sites has been listed on the *National Register of Historic Places*, but 150 are considered by DOE to be eligible for nomination as historic properties (see Table 3-21) based on National Register eligibility criteria. Several reports describe the specific procedures used to study and protect these cultural sites (DIRS 104807-CRWMS M&O 1995, all; DIRS 104810-CRWMS M&O 1995, all; DIRS 104813-CRWMS M&O 1995, all; DIRS 104814-CRWMS M&O 1995, all; DIRS 104818-CRWMS M&O 1995, all; DIRS 104819-CRWMS M&O 1995, all; DIRS 104822-CRWMS M&O 1995, all; DIRS 104824-CRWMS M&O 1995, all; DIRS 103198-YMP 1992, all). DIRS 104558-DOE (1988, all) describes how the Department meets its responsibilities under Section 106 of the National Historic Preservation Act and the American Indian Religious Freedom Act, and interactions with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer.

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Table 3-21. Sites in the analyzed land withdrawal area potentially eligible for the *National Register of Historic Places.*

Type	Number
Temporary camps	43
Extractive localities	14
Processing localities	9
Localities	77
Caches	2
Stations	1
Historic sites	4
Total	***150***

This EIS separates archaeological sites into two broad groups, prehistoric and historic, separated by the first contact between American Indians and Euroamericans; in the Great Basin, this contact occurred in the early 1800s. The oldest prehistoric sites in southern Nevada are about 11,000 years old. These sites include one or more of the following features: temporary campsites, rock art, scattered lithic artifacts, quarries, plant-processing remains, hunting blinds, and rock alignments. The sites are categorized as temporary camps, extractive localities, processing localities, localities, caches, and stations. Historic sites include mining sites, ranching sites, transportation and communication sites, and some Cold War facilities. The following paragraphs define eligible types of sites at Yucca Mountain in each group (Table 3-21).

Temporary Camps. When occupied by a group of people, a temporary camp was a hub of activity for raw materials processing, implement manufacturing, and maintenance and general living activities. Camp artifacts typically include debris and discards from the making of stone tools, projectile points, bifacial stone tools, cores, milling stones, pottery, specialized tools, hearths, shelters, structures, and art. The nature and diversity of artifacts and features are the basis for designating a site as a temporary camp.

Extractive Localities. These were sites for specific extractive or resource-procurement tasks. They probably were occupied for short periods and for such limited activities as toolstone quarrying, hunting, and seed gathering. A single locality can contain isolated artifacts or large quantities of artifacts that reflect specific activities. In comparison to temporary camps, extractive localities have a low diversity of artifacts. Extractive locality artifacts include isolated projectile points or bifacial stone tools where hunting occurred, toolstone quarries with thousands of flakes, diffuse scatters of lithic flakes where plant materials were gathered, hunting blinds, and *tinajas* or water-catchment basins.

Processing Localities. Specific resource-processing tasks occurred at processing localities. These localities probably were occupied only for short periods and for limited activities such as butchering, milling, and roasting. A single site can contain an isolated artifact or large quantities of artifacts that reflect specific activities. Like extractive localities, processing localities have a low diversity of artifacts. Examples of processing localities include stone tool manufacturing stations, milling stations for processing food, diffuse scatters containing stone tools for processing meat and hides, hearths, and roasting pits.

Localities. This category includes sites that might have been either extractive or processing localities but for which there is not enough information to determine if such activities occurred.

Caches. Caches are temporary places for storing resources or artifacts. They include sealed rock shelters, rock piles, rock rings without evidence of habitation, rock alignments, brush piles held in place by rocks, and storage pits. A cache can also be an association of similar artifacts such as heat-treated bifacial stone tools, projectile points, and snares, or such resources as toolstone blanks and firewood in or on a natural feature such as at the base of a tree, in a rock shelter, or in a mountain saddle. Caches are distinguished from localities as places for storing resources, rather than as places of procurement or processing.

Stations. Stations are sites where groups gathered to exchange information about such things as game movement, routes of travel, and ritual activities. Examples of stations are rock cairns marking routes of travel, isolated petroglyphs and pictographs, geoglyphs, and observation points and overlooks.

Historic Sites. Historic sites are contemporaneous with or postdate the introduction of European influences in the region. Historic archaeological sites are few in number in the project area, usually represented by a small scatter of artifacts (cans and bottles). These short-term activities were related to mining, ranching, and transportation.

3.1.6.2 Native American Interests

3.1.6.2.1 *Yucca Mountain Project Native American Interaction Program*

In 1987, DOE initiated the Native American Interaction Program to consult and interact with tribes and organizations on the characterization of the Yucca Mountain site and the possible construction and operation of a repository. These tribes and organizations—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone people from Arizona, California, Nevada, and Utah—have cultural and historic ties to the Yucca Mountain area.

The Native American Interaction Program concentrates on the protection of cultural resources at Yucca Mountain and promotes a government-to-government relationship with the tribes and organizations. Its purpose is to help DOE comply with various Federal laws and regulations, including the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the National Historic Preservation Act, the Native American Graves Protection and Repatriation Act, DOE Order 1230.2 (*American Indian and Tribal Government Policy*), and Executive Orders 13007 (*Indian Sacred Sites*) and 13084 (*Consultation and Coordination with Indian Tribal Governments*). These regulations mandate the protection of archaeological sites and cultural items and require agencies to include Native Americans and Federally recognized tribes in discussions and interactions on major Federal actions.

Initial studies identified three tribal groups—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone—whose cultural heritage includes the Yucca Mountain region (DIRS 104927-Stoffle 1987, p. 5-13). Additional ethnographic efforts eventually identified 17 tribes and organizations involved in the Yucca Mountain Project Native American and cultural resource studies. Figure 3-22 shows the traditional boundaries and locations of the 17 tribes and organizations.

Of the 17 tribal groups, 15 are Federally recognized tribes. The Pahrump Paiute Indian Tribe, which consists of a group of Southern Paiutes living in Pahrump, Nevada, has applied for Federal tribal recognition but to date has not received it. In addition, the Las Vegas Indian Center is not a Federally recognized tribe, but DOE included it in the Native American Interaction Program because it represents the urban Native American population of Las Vegas and Clark County, Nevada (DIRS 103465-Stoffle et al. 1990, p. 7).

The 17 tribes and organizations have formed the Consolidated Group of Tribes and Organizations, which consists of officially appointed tribal representatives who are responsible for presenting their respective tribal concerns and perspectives to DOE. The primary focus of this group has been the protection of cultural resources and environmental restoration at Yucca Mountain. Members of the group have participated in many ethnographic interviews and have provided DOE valuable insights into Native American cultural and religious values and beliefs. These interactions have produced several reports that record the regional history of Native American people and the interpretation of Native American cultural resources in the Yucca Mountain region (DIRS 104958-DOE 1989, pp. 30 to 74; DIRS 103465-Stoffle et al. 1990, pp. 11 to 25; DIRS 104959-DOE 1990, pp. 23 to 49). In addition, tribal representatives have identified and discussed traditional and current uses of plants in the area (DIRS 103464-DOE 1989, pp. 22 to 139).

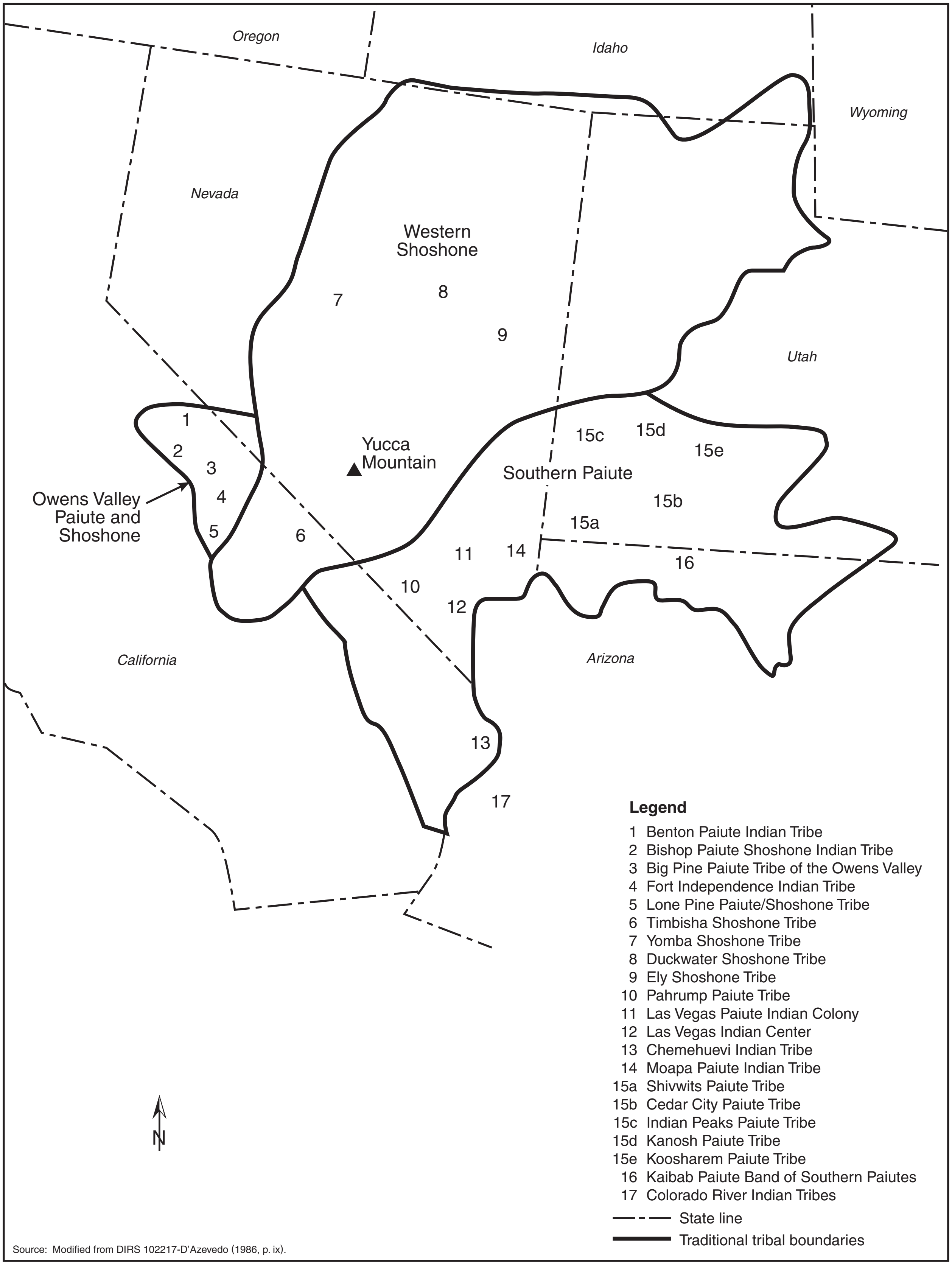

Figure 3-22. Traditional boundaries and locations of tribes in the Yucca Mountain region.

3.1.6.2.2 *Native American Views of Affected Environment*

During the EIS scoping process, DOE visited many tribes to encourage their participation. Members of the Consolidated Group of Tribes and Organizations designated individuals who represented the three tribal entities (Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone) to document their viewpoints on the Yucca Mountain area. This group, the American Indian Writers Subgroup, prepared a resource document that provides Native American perspectives on the repository (DIRS 102043-AIWS 1998, all). This report also describes the relationship between Native American people and DOE and discusses impacts of the Proposed Action while recommending impact mitigation approaches for reducing potential impacts to Native American resources and other heritage values in the Yucca Mountain region. In addition to the general and specific cultural resources issues, which are summarized in the following paragraphs, the report covers other critical topics, including concerns for occupational and public health and safety, environmental justice and equity issues, and social and economic issues. The report also provides recommendations for the conduct of appropriate consultation procedures for the repository and associated activities, and requests Native American participation in development of project resource management approaches to enable the incorporation of accumulated centuries of ethnic knowledge in long-term cultural resource protection strategies.

Native Americans believe that they have inhabited their traditional homelands since the beginning of time. Archaeological surveys have found evidence that Native Americans used the immediate vicinity of Yucca Mountain on a temporary or seasonal basis (DIRS 103465-Stoffle et al. 1990, p. 29). Native Americans emphasize that a lack of abundant artifacts and archaeological remains does not mean that their people did not use a site or that the land is not an integral part of their cultural ecosystem. Native Americans assign meanings to places involved with their creation as a people, religious stories, burials, and important secular events. The traditional stories of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples identify such places, including the Yucca Mountain area.

Native Americans believe that cultural resources are not limited to the remains of native ancestors but include all natural resources and geologic formations in the region, such as plants and animals and natural landforms that mark important locations for keeping their historic memory alive and for teaching their children about their culture. Equally important are the water resources and minerals in the Yucca Mountain region. Native Americans used traditional quarry sites to make tools, stone artifacts, and ceremonial objects; many of these sites are *power places* associated with traditional healing ceremonies. Despite the current physical separation of tribes from Yucca Mountain and neighboring lands, Native Americans continue to value and recognize the meaningful role of these lands in their culture and continued survival. Many areas in the Yucca Mountain region are important to them. Fortymile Canyon was an important crossroad where a number of traditional trails from such distant places as Owens Valley, Death Valley, and the Avawtz Mountain came together. Oasis Valley was an important area for trade and ceremonies. Native Americans believe that Prow Pass was an important ceremonial site and, because of this religious importance, have recommended that DOE conduct no studies in this area. Other areas are important based on the abundance of artifacts, traditional-use plants and animals, rock art, and possible burial sites.

According to Native Americans, the Yucca Mountain area is part of the holy lands of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples. Native Americans generally do not concur with the conclusions of archaeological investigators that their ancestors were highly mobile groups of aboriginal hunter-gatherers who occupied the Yucca Mountain area before Euroamericans began using the area for prospecting, surveying, and ranching. They believe that these conclusions overlook traditional accounts of farming that occurred before European contact. Yucca Mountain and nearby lands were central in the lives of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples, who shared them for religious ceremonies, resource uses, and social events. Native Americans value the cultural resources in these areas, viewing them in a holistic manner. They believe that the water, animals, plants, air, geology, and artifacts are interrelated and dependent on each other for existence.

3.1.7 SOCIOECONOMICS

To define the existing conditions for the socioeconomic environment in the Yucca Mountain region, DOE determined the current economic and demographic status in a well-defined region (called the *region of influence*) near the site of the proposed repository. DOE based its definition of the socioeconomic region of influence on the distribution of the residences of current employees of the Department and its contractors who work on the Yucca Mountain Project or at the Nevada Test Site. The region of influence, therefore, consists of the three Nevada counties (Clark, Lincoln, and Nye Counties) where about 98 percent of the DOE 2001 workforce lives. The region of influence includes Lincoln County because of the possibility that DOE could build and operate an intermodal transfer station there. The Department used the residential distribution, which reflects existing commuting patterns, to estimate the future distribution of direct workers associated with the Proposed Action and the No-Action Alternative.

The socioeconomic region of influence for the Proposed Action, consisting of Clark, Lincoln, and Nye Counties in Southern Nevada, is shown in Figure 3-23. Clark County contains the City of Las Vegas and its suburbs. Based on a count of workers in a 1994 data report, 79 percent of the Yucca Mountain Project and Nevada Test Site onsite employees live in Clark County and approximately 19 percent live in Nye County (Table 3-22).

Table 3-22. Distribution of Yucca Mountain Project and Nevada Test Site employees by place of residence.[a]

Place of residence	Onsite workers	Percent of total
Clark County	1,268	79
Lincoln County	5	<1
Nye County	308	19
Total region of influence[b]	1,581	98
Outside region of influence	31	2
Total respondents[b]	***1,612***	***100.0***

a. Source: DIRS 104957-DOE (1994, Table 2-7).
b. Subtotals may not add to totals because of rounding.

DOE received numerous reports from affected units of local government providing socioeconomic baseline environmental information. In addition, DOE regularly requests and receives economic and demographic data from local and State of Nevada agencies. The data and reports contain information that characterizes the existing community environment, provides assessments of economic development, or includes basic economic and demographic trends. DOE reviewed these reports and incorporated pertinent information in this EIS.

DOE used the REMI Economic-Demographic Forecasting System model to estimate the baseline for population, employment, and three other economic measures: Gross Regional Product, real disposable income, and State and local government spending. The baseline was projected from 2000 to 2035 for the three counties in the Region of Influence, for the Rest of Nevada, and for all of Nevada. This baseline information is provided in Table 3-23. The REMI model was used to estimate changes to the socioeconomic measures from the baseline based on different cases for repository construction and operation and for different transportation options. These changes from the baseline are discussed in Chapters 4 and 6.

The version of the REMI model used for the Final EIS is based on historical data through 1997. This model was updated to include State of Nevada employment data for 1998. Additional local information was incorporated in the baseline projections. These included expected near-term changes and long-term stability in the mining industry in Nye County; changes in employment by DOE during 1999 and 2000; and expected increases in hotel-casino employment as a result of openings of new hotels and casinos through 2001. Finally, the baselines were adjusted to account for population estimates and projections made for Clark and Nye Counties and by the Nevada State Demographer's Office.

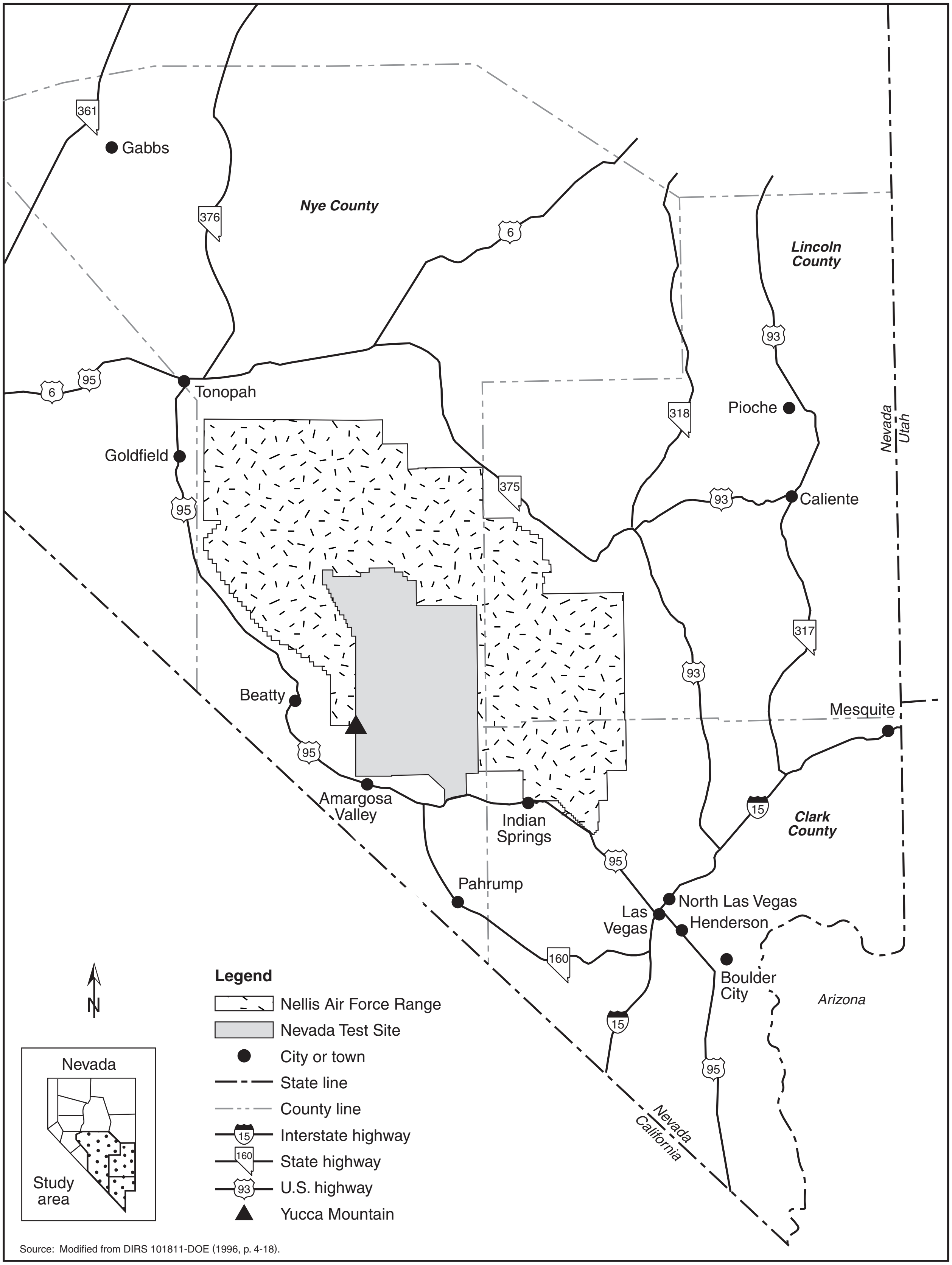

Figure 3-23. Socioeconomic region of influence.

Table 3-23. Baseline values for population, employment, and economic variables, 2000 to 2035.

Economic parameter	2000	2005	2010	2015	2020	2025	2030	2035
Population[a]								
Clark County	1,383,113	1,633,935	1,836,548	2,017,067	2,174,210	2,327,484	2,492,956	2,668,860
Nye County	40,656	49,387	56,759	62,641	67,351	72,047	76,952	82,417
Lincoln County	4,389	4,421	4,405	4,521	4,644	4,824	5,027	5,281
Rest of Nevada	598,047	645,720	690,171	753,120	814,231	872,195	929,565	992,999
All of Nevada	2,026,205	2,333,463	2,587,883	2,837,349	3,060,436	3,276,550	3,504,500	3,749,557
Employment[a]								
Clark County	830,265	909,842	980,618	1,045,289	1,099,697	1,151,187	1,211,596	1,283,384
Nye County	12,883	14,665	16,324	17,437	18,205	18,917	19,812	20,968
Lincoln County	2,249	2,419	2,527	2,612	2,664	2,732	2,835	2,987
Rest of Nevada	384,756	416,109	438,589	460,244	478,861	497,120	519,138	547,305
All of Nevada	1,230,153	1,343,035	1,438,058	1,525,582	1,599,427	1,669,956	1,753,381	1,854,644
Gross Regional Product[a,b,c]								
Clark County	45.3	50.2	55.7	61.1	66.1	71.3	77.5	84.7
Nye County	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3
Lincoln County	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Rest of Nevada	20.9	23.7	26.2	28.6	31.0	33.4	36.1	39.4
All of Nevada	66.9	74.9	82.9	90.8	98.3	106.0	114.9	125.6
Government Spending[a,b,c]								
Clark County	4.4	5.4	6.4	7.3	8.1	8.9	9.8	10.8
Nye County	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3
Lincoln County	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rest of Nevada	2.1	3.3	3.7	4.1	4.6	5.0	5.4	6.0
All of Nevada	6.6	8.8	10.2	11.7	12.9	14.1	15.5	17.2
Real Disposable Income[a,b,c]								
Clark County	34.8	37.0	42.7	47.9	52.6	57.4	63.6	71.3
Nye County	0.6	0.8	0.9	1.1	1.2	1.2	1.4	1.5
Lincoln County	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Rest of Nevada	16.5	16.9	18.9	20.9	22.8	24.8	27.3	30.1
All of Nevada	52.0	54.7	62.6	69.9	76.6	83.6	92.3	103.1

a. Values from State Demographer and Local Agencies' Baseline (DIRS 157089-TtNUS 2001, Appendix B, Attachments 5 to 10).
b. 2001 dollars, in billions.
c. Sums may not add to totals because of rounding.

Chapter 3 cites information, when available, from the 2000 Census as gathered by the Bureau of the Census. The analysis of impacts to socioeconomic parameters, including population and employment, in subsequent chapters are projected, however, from baselines developed with input from the State of Nevada and local sources.

Section 3.1.7.2 discusses employment estimates by industrial sectors by county in the region of influence.

3.1.7.1 Population

Southern Nevada has been and continues to be among the fastest-growing areas in the country. During the 1980s, the population of the region of influence had an average annual growth rate of 4.8 percent, with a total growth of 66.5-percent for the decade, adding more than 29,000 people annually and reaching 780,000 residents in 1990. In comparison to the State of Nevada, which had a growth of 50.1 percent between 1980 and 1990, the United States had a growth of less than 10 percent during the same period (DIRS 102119-Bureau of the Census 1995, all). This trend has continued during the 1990s. By 2000, the population of Clark County was about 1.4 million people. The region of influence grew by 88 percent from 1990 to 2000, averaging almost 65,000 new residents annually. In 2000, the estimated population

2000 CENSUS DATA AND UPDATED REMI MODEL

After issuing the Draft EIS and reviewing public comments on that document, DOE began revisiting its socioeconomic baseline projections and estimated impacts for the Final EIS utilizing data available from the State of Nevada and local communities. The revisions included an estimated baseline projection to 2035 for the socioeconomic parameters considered in the EIS.

In March 2001, while the preparation process for this Final EIS was under way, the Bureau of the Census released its county-level population data for Nevada based on its 2000 Census. In addition, DOE received a newly updated REMI model, with historical data through 1998. DOE then prepared an additional baseline projection, using the updated REMI model, for the Region of Influence, the Rest of Nevada, and the State of Nevada. This additional baseline incorporated State employment data for 1999, DOE employment for Nevada in 2000, expected additional hotel-casino employment due to an increase in the number of hotel rooms, expected near-term changes and long-term stability in the mining industry in Nye County, and population estimates and projections made for Clark and Nye Counties and by the Nevada State Demographer's Office. The data was adjusted such that 2000 populations match the Decennial Census estimates. The census-anchored baseline was compared to the "local-based" forecast shown in Table 3-23. The census-anchored baseline and the percentage change from the State Demographer and Local Agencies' Baseline forecast for Nevada are listed below:

	Projected 2000 Census-anchored numbers by year, 2000 to 2035							
	2000	2005	2010	2015	2020	2025	2030	2035
Population[a]								
Clark County	1,375,766	1,685,159	1,892,536	2,068,053	2,233,042	2,378,426	2,550,975	2,743,684
Nye County	32,485	41,295	48,407	54,621	60,083	65,516	71,377	77,788
Lincoln County	4,165	4,178	4,192	4,328	4,532	4,717	4,888	5,062
Rest of Nevada	585,842	652,101	706,325	755,923	802,826	852,301	905,780	961,020
All of Nevada	1,998,258	2,382,733	2,651,460	2,882,925	3,090,483	3,300,960	3,533,020	3,787,554
Percent difference[b]	-1.38	2.11	2.46	1.61	0.98	0.74	0.81	1.01
Employment[a]								
Clark County	840,748	922,302	1,000,912	1,080,506	1,147,571	1,197,196	1,253,724	1,337,723
Nye County	13,001	14,947	16,824	18,360	19,592	20,594	21,771	23,465
Lincoln County	2,042	2,195	2,306	2,402	2,471	2,525	2,601	2,728
Rest of Nevada	384,364	412,141	437,244	463,337	483,473	497,075	514,505	543,526
All of Nevada	1,240,154	1,351,585	1,457,286	1,564,605	1,653,107	1,717,390	1,792,601	1,907,442
Percent difference[b]	0.81	0.64	1.34	2.56	3.36	2.84	2.24	2.85

a. Values from 2000 Census-Anchored Baseline (DIRS 157089-TtNUS 2001, Appendix C, Attachments 5 to 10)

b. Percent difference is for the Nevada (total) going from the State Demographer and Local Agencies' Baseline (Table 3-23) to the 2000 Census-Anchored Baseline shown above.

DOE also used the updated REMI model to estimate changes to the baseline for some of the repository design scenarios and transportation options to determine if the use of the revised model would provide meaningfully different estimates of changes in the economic and demographic measures. Sensitivity analyses revealed that the incremental differences between the two were generally small, and that differences in socioeconomic changes for analyzed scenarios and transportation options using the updated model were not meaningful.

DOE elected to base its socioeconomic projections and impact estimates in this Final EIS on the most recently available information from State and local resources, without consideration of the Decennial Census data, in consideration of the critiques received from commenters and for the following reasons:

- Analysis showed that the incremental differences or potential socioeconomic impacts associated with Yucca Mountain Repository activities are basically insensitive to the baseline used or which of the two versions of the model is used.
- The State of Nevada and local communities have not yet made available their independent estimates based on the 2000 Census data.
- There is some uncertainty involving what the final population totals would be for the Census data at the county level.

Similarly, DOE based its estimated population distribution and growth within 80 kilometers (50 miles) of the repository on projections to 2035 using the information from State and local sources. The 80-kilometer population distributions for 2000 and 2035 are shown in Figure 3-25.

of the region of influence was about 1.41 million people. Led by Clark County, Nevada is the fastest growing state in the country. From 1990 to 2000, Nevada had a total growth of 66.3 percent compared to the 13.1-percent overall growth of the United States.

Las Vegas and the immediate surrounding area dominate the Clark County population. The Las Vegas economy is driven by the growth of the hotel, amusement and recreation, and eating and drinking sectors associated with the gaming industry. As the popularity of gaming grew in the 1970s, 1980s, and 1990s, Las Vegas evolved as one of the country's major tourism and convention destinations. In 2000, Las Vegas hosted 35.8 million visitors, contributing $31.5 billion to the local economy (DIRS 148157-LVCVA 1999, all). The tourism trend is expected to continue well into this century. However, there are a number of economic indicators that suggest the growth in the gaming industry is slowing. The relatively moderate housing costs, temperate climate, abundance of recreational opportunities, favorable business conditions, and absence of a State income tax have contributed to commercial and residential growth. The number of retirees (from across the United States) moving to communities in the region of influence is escalating.

Nye County, which has been the site of booms and busts due to fluctuating mining activity and the recent decline of Nevada Test Site employment, is home to approximately 4 percent of the Yucca Mountain Project employees who work in Nevada (DIRS 155987-DOE 2001, Tables 3-14 and 3-22). Pahrump, in southern Nye County, is experiencing growth caused primarily by inmigrating retirees and its proximity to Las Vegas. In 2000, Nye County had about 32,500 residents, having experienced an 82.7-percent growth in the 1990s. The 2000 population in Lincoln County was about 4,200, up from about 3,800 in 1990, a growth of approximately 10.3 percent.

Although the annual growth rate of the region of influence is likely to slow from the extraordinary pace of the 1990s, the population should continue to grow at a rate of 2 to 4 percent a year in this decade. Clark County will continue to lead the population growth in the foreseeable future in the region of influence.

The region of influence includes a number of incorporated cities and towns as well as unincorporated communities (Table 3-24). The largest city in Clark County is Las Vegas, followed by Henderson. In 2000, Las Vegas had a population of about 480,000 compared to Henderson, which had about 180,000 residents. Nye County has no incorporated cities, but the largest community is unincorporated Pahrump, which had an estimated population of about 25,000 in 2000. Lincoln County has only one incorporated city, Caliente, which is the largest community with a 2000 population of about 1,100.

Clark County has a population density of about 140 persons per square mile. Lincoln County has approximately 0.4 person per square mile, and Nye County has a population density of about 1.4 persons per square mile.

Population growth in the State of Nevada and Clark County is expected to exceed average national trends through 2035. The explosive population growth in Clark County is expected to slow, but remain well above national averages, at about 3 percent through 2035. Clark County will continue to house approximately 97 percent of the population in the region of influence. Nye County is also expected to grow at an accelerated rate, with an average annual increase of approximately 2 percent to 2035. Lincoln County is expected to experience less than 1-percent annual growth through the first third of this century. Figure 3-24 shows estimated populations for the region of influence and the State of Nevada, projected out to 2035.

3.1.7.2 Employment

Of the three counties that comprise the region of influence, Clark County has by far the largest economy; in 2000, the estimated employment was about 840,000. This constituted 98 percent of the regional

Table 3-24. Population of incorporated cities and selected unincorporated towns, 1991 to 2000.[a]

Jurisdiction	1991[b]	1995[b]	2000[c]
Clark County			
Boulder City	13,000	14,000	15,000
Henderson	77,000	120,000	180,000
Indian Springs[d]	N/A[e]	N/A	1,300
Las Vegas	290,000	370,000	480,000
Mesquite	2,100	5,100	9,400
North Las Vegas	51,000	78,000	120,000
Nye County			
Amargosa Valley[d]	920	1,200	1,200
Beatty[d]	1,800	1,900	1,200
Gabbs[d,f]	680	360	320
Pahrump[d]	8,800	15,000	25,000
Tonopah[d]	3,600	3,400	2,600
Lincoln County			
Caliente	1,100	1,200	1,100

a. Population numbers have been rounded to two significant figures.
b. Sources:
 (1) DIRS 100065-NSDO (1998, all).
 (2) DIRS 148031-PIC (1993, all).
 (3) DIRS 148060-Levy (1997, all).
 (4) DIRS 153928-NDA (2000, all).
c. Source: DIRS 155872-Bureau of the Census (2000, place totals).
d. Selected unincorporated towns.
e. N/A = not available.
f. Gabbs unincorporated in May 2001.

employment and about 68 percent of the State employment. During the same year Nye County had an employment base of about 13,000, and the Lincoln County employment base was about 2,000. Clark County should continue to lead employment growth in the region of influence.

Between 1980 and 1990, Clark County added an average of 19,000 jobs a year (Table 3-25). Since 1990 that pace has increased to more than 38,000 new jobs a year. *Total employment* increased 35 percent between 1990 and 1995, adding about 160,000 jobs. In 2000, Clark County added 3,000 jobs a month to its labor force. The services sector, which includes hotels, eating and drinking establishments, and amusement and recreation facilities, is the largest employer in Clark County, representing 45 percent of the employment in 2000.

Although Nye County's employment increased between 1980 and 1990, it declined to about 11,000 in 1995, a decrease of 15 percent (Table 3-26). Employment rebounded and by 2000 there were approximately 13,000 jobs in the county. Services represents the largest employment sector in the Nye County economy. In 2000, services comprised 43 percent of Nye County's employment and retail trade made up an additional 14 percent. Lincoln County's employment declined between 1990 and 1995 after growth during the 1980s (Table 3-27). Employment had declined to about 2,000 positions by 2000. As in Clark and Nye Counties, services represented the largest sector of the Lincoln County economy, about 35 percent. Employment in Federal, State, and local government agencies represented a significant presence in the County's employment, about 29 percent.

Las Vegas, in Clark County, has one of the fastest growing economies in the country. The rapid growth of the Las Vegas area is driven by the gaming and tourism industry. For each hotel room constructed, an employment multiplier effect creates an estimated 2.5 direct and indirect (composite) jobs. About 4,200 hotel rooms were added in 2000 alone. Despite an inventory of more than 124,000 rooms, hotels consistently operate at 90 percent occupancy, reaching 97 percent on weekends.

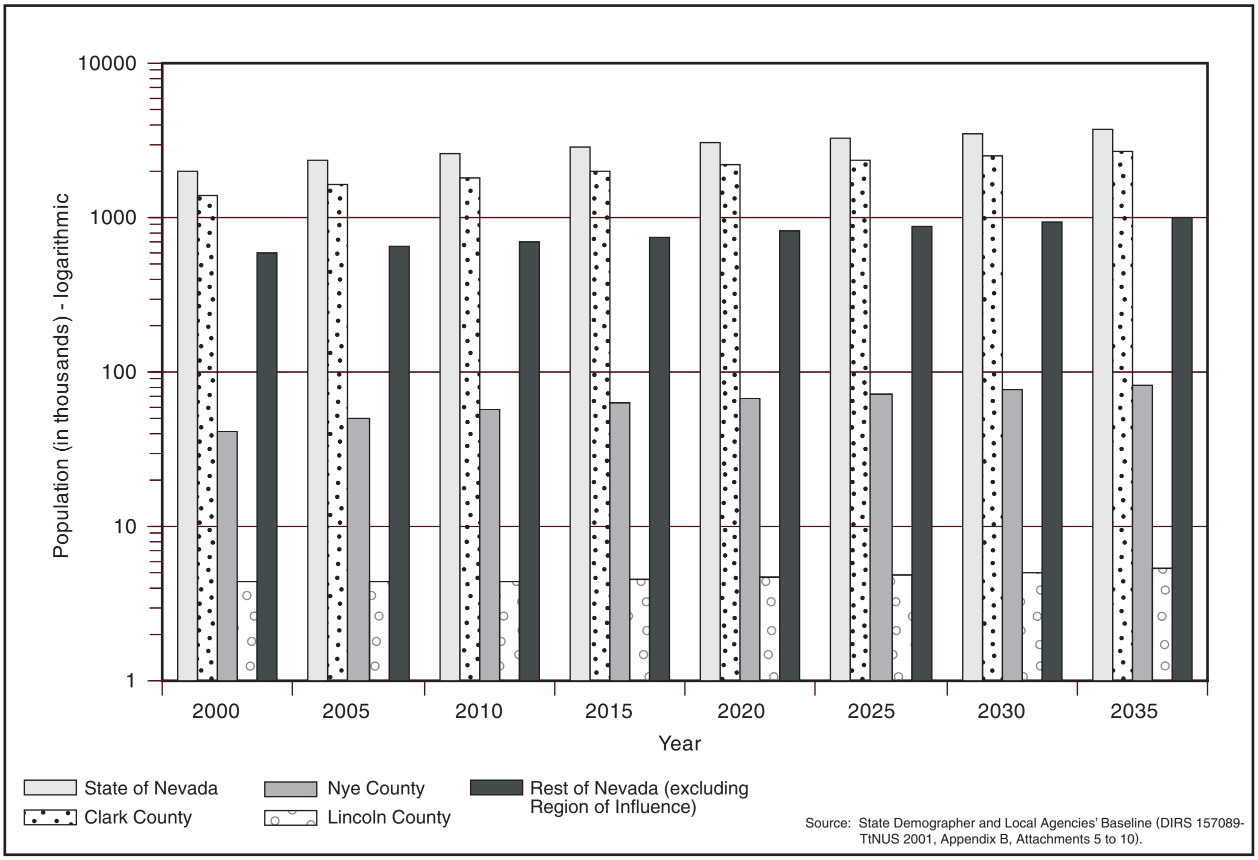

Figure 3-24. Estimated populations to 2035 for the region of influence and the State of Nevada.

Hundreds of new jobs are added to the regional economy each month, and many job seekers have come to the area (primarily Clark County). Some of these new arrivals, however, lack the necessary job skills or experience that area employers require. As a result, Clark County has maintained a healthy, relatively low unemployment rate, but one that remains near State and national averages. In 2000, Clark and Nye Counties had unemployment rates of 4.3 percent and 5.4 percent, respectively (DIRS 155818-NDETR 2001, all). The average in the State of Nevada was about 4.4 percent, and nationwide the unemployment rate was about 4.0 percent. Lincoln County had an unemployment rate above the national average at 6.6 percent (DIRS 155818-NDETR 2001, all). Onsite employment levels at the Exploratory Studies Facility remained relatively constant between 1995 and 2000, and are not likely to fluctuate substantially through the end of site characterization activities.

In 2000, an average of about 2,320 workers (220 work on the site and 2,100 off the site) worked on the Yucca Mountain Project. Most offsite workers are employed in the Las Vegas area (DIRS 155987-DOE 2001, Table 3-1).

As would be expected, projected employment in the region of influence broadly reflects population trends. The number of jobs in Clark County will reach approximately 1.3 million in 2035, up from 840,000 in 2000. Clark County will host 98 percent of the employment opportunities in the three-county region of influence. Nye County will add approximately 10,000 additional workers by 2035 from the 13,000 base in 2000. Lincoln County employment will expand from 2,040 in 2000 to approximately 2,700 in 2035.

Table 3-25. Clark County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	1,300	3,900	6,200	9,400
Mining	590	820	1,200	1,500
Construction	16,000	41,000	53,000	81,000
Manufacturing	7,300	12,000	18,000	21,000
Transportation and public utilities	14,000	21,000	29,000	38,000
Wholesale trade	6,500	14,000	19,000	25,000
Retail trade[d]	44,000	72,000	98,000	134,000
Finance, insurance, and real estate	20,000	32,000	44,000	62,000
Farms	420	400	300	350
Services[d]	120,000	210,000	290,000	374,000
Government				
Federal Government - civilian	4,800	6,900	7,800	8,100
Federal Government - military	11,000	11,000	9,500	10,000
State and local government	22,000	33,000	45,000	66,000
Totals[e]	***268,000***	***458,000***	***621,000***	***830,000***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are included in Retail Trade.
e. Sums may not add to totals because of rounding.

Table 3-26. Nye County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	50	70	110	110
Mining	1,100	2,000	1,400	830
Construction	410	390	560	880
Manufacturing	88	160	250	310
Transportation and public utilities	210	280	280	400
Wholesale trade	25	49	100	180
Retail trade	530	960	1,200	1,800
Finance, insurance, and real estate	360	290	450	510
Farms	220	260	210	260
Services[d]	4,100	7,700	5,200	5,300
Government				
Federal Government - civilian	130	200	200	200
Federal Government - military	100	77	53	81
State and local government	540	930	1,200	2,000
Totals[e]	***7,860***	***13,400***	***11,200***	***12,900***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are included in Retail Trade.
e. Sums may not add to totals because of rounding.

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Table 3-27. Lincoln County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	4	30	22	23
Mining	310	30	18	51
Construction	75	47	44	32
Manufacturing	12	10	10	19
Transportation and public utilities	96	88	62	120
Wholesale trade	12	10	17	42
Retail trade	310	250	270	380
Finance, insurance, and real estate	51	47	68	77
Farms	160	180	150	160
Services[d]	380	1,200	869	680
Government				
Federal Government - civilian	25	45	39	36
Federal Government - military	12	12	8	11
State and local government	360	480	560	620
Totals[e]	***1,860***	***2,430***	***2,140***	***2,250***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are contained in Retail Trade.
e. Sums may not add to totals because of rounding.

The 1997 per-capita income of Clark County was about $26,200, near the State's average of about $26,600. The per-capita income in Nye County was $20,400 and in Lincoln County it was $18,400. The U.S. average was $25,300 in the same year (DIRS 155987-DOE 2001, Tables: 1994-1998 Per Capita Income, Nevada vs. Western States; 1970-1998 Total & Per Capita Income in Nevada; and 1989-1997 Per Capita Income in Nevada, by County).

3.1.7.3 Payments-Equal-to-Taxes

Another issue of interest is the DOE Payments-Equal-To-Taxes Program. Section 116(c)(3)(A) of the Nuclear Waste Policy Act, as amended, requires the Secretary of Energy to "…grant to the State of Nevada and any *affected unit of local government* an amount each *fiscal year* equal to the amount such State or affected unit of local government, respectively, would receive if authorized to tax site characterization activities…." The Yucca Mountain Site Characterization Office is responsible for implementing and administering this program for the Yucca Mountain Project. DOE acquired data from the project organizations that purchase or acquire property for use in Nevada, have employees in Nevada, or use property in Nevada. These organizations include Federal agencies, national laboratories, and private firms. Not all of them have a Federal exemption, so they pay the appropriate taxes. The purchases (sales and use tax), employees (business tax), and property (property or possessory use taxes) of the Yucca Mountain Project organizations that exercise a Federal exemption are subject to the Payments-Equal-To-Taxes Program (DIRS 156763-YMP 2001, all).

The actual sales and use taxes, property taxes, and Nevada business taxes paid by Yucca Mountain Project organizations that are not exempted from tax payment obligations for May 1986 through June 2000 have been totaled. These organizations paid sales or use taxes of $2.5 million for purchases consumed in Clark County and $5.1 million in Nye County, paid property or possessory taxes of about $90,000 in Clark County and $37,000 in Nye County, and paid Nevada business taxes of about $810,000 (DIRS 156763-YMP 2001, all).

The Payments-Equal-To-Taxes for sales or use taxes from May 1986 through June 2000 was about $4.4 million for purchases consumed in Clark County and $450,000 in Nye County. For property taxes it was about $940,000 in Clark County, $46 million in Nye County, $8,000 in Lincoln County, and $3,700 in Esmeralda County. For Nevada business taxes (Clark, Nye, Esmeralda, and Lincoln Counties), about $160,000 was paid (DIRS 156763-YMP 2001, all).

3.1.7.4 Housing

Spurred by the rapid population growth and soaring employment opportunities, the residential housing market is strong and steady in the Las Vegas area. From 1992 to 1996, annual sales of new homes exceeded 16,000 units. In 1999, a record 21,200 units were sold. In 2000, 20,500 new homes and 29,500 existing homes were sold. More than 400 residential developers sell properties in the Las Vegas area, leading to a highly competitive market. The competitive environment has kept price increases to the rate of inflation. Eighty-five percent of the new homes sold were priced between $100,000 and $200,000. In 2000, the median price of a new home was about $160,000 and the median price of a resale home was about $132,000. These sale prices are slightly below the national median prices of $165,000 for new homes and $143,500 for existing units. Large master-planned communities are common, and average about 30 percent of the total home sales. Steady employment and population growth should continue to spur demand for housing. Sustained growth will depend on further development of large-scale resort and gaming projects.

The housing stock of Clark County in 1990 was about 320,000 units, which consisted of about 157,000 single-family units, 130,000 multifamily units, and 33,000 mobile homes or other accommodations. About 290,000 of these units were occupied (DIRS 148097-Bureau of the Census 1998, all) resulting in 2.5 persons per household. The number of households in Clark County in 2000 was about 560,000 units (DIRS 155872-Bureau of the Census 2000, all).

The housing stock of Nye County in 1990 was about 8,100 units, which consisted of about 2,300 single-family units, 560 multifamily units, and 5,200 mobile homes or other accommodations. About 6,700 of these units were occupied, resulting in 2.5 persons per household (DIRS 148097-Bureau of the Census 1998, all). The number of households in Nye County in 2000 was about 15,900 (DIRS 155872-Bureau of the Census 2000, all).

The housing stock of Lincoln County in 1990 was about 1,800 units, which consisted of about 1,000 single-family units, 160 multifamily units, and 600 mobile homes or other accommodations. About 1,300 of these units were occupied, resulting in 2.6 persons per household (DIRS 148097-Bureau of the Census 1998, all). The number of households in Lincoln County in 2000 was about 2,200 (DIRS 155872-Bureau of the Census 2000, all).

Because most population and employment growth in the region of influence will occur in Clark County, most housing growth also will occur there. The only other area in the region likely to see large growth is Pahrump in southern Nye County. Housing changes in Lincoln County probably will be minimal in the foreseeable future.

3.1.7.5 Public Services

Education. In the 2000-2001 school year, the region of influence contained about 223 public elementary and middle schools, 37 public high schools, 13 alternative schools, 4 special education schools, an Advanced Technology Academy, an adult education center, and 3 charter schools (DIRS 157141-NDE 2001, all). Clark County opened 11 of these schools in the 2000-2001 school year. The average pupil-teacher ratio was about 21-to-1 for elementary schools and 19-to-1 for secondary schools (DIRS 157142-NDE 2001, all). In 1999, the national pupil-teacher ratio was about 19-to-1 for elementary schools and

15-to-1 for secondary schools (DIRS 155819-NCES 2000, all). Clark County has the tenth-largest school district in the country; during the 2000-2001 school year, Clark County had about 258 schools and nearly 232,000 students (Table 3-28). During the same period, Nye County had approximately 5,300 students, and Lincoln County had about 1,020 students (DIRS 155820-NDE 2001, all).

Table 3-28. Enrollment by school district and grade level.[a,b]

District	Actual 1996-1997[c]	Actual 2000-2001[d]
Clark County		
Prekindergarten	1,100	1,100
Kindergarten	15,000	19,000
Elementary (grades 1-6)	90,000	120,000
Secondary (grades 7-12)	73,000	94,000
District totals[e]	179,000	232,000
Nye County		
Prekindergarten	43	54
Kindergarten	370	360
Elementary (grades 1-6)	2,300	2,500
Secondary (grades 7-12)	2,200	2,300
District totals[e]	4,970	5,290
Lincoln County		
Prekindergarten	22	15
Kindergarten	57	62
Elementary (grades 1-6)	400	370
Secondary (grades 7-12)	630	570
District totals[e]	1,110	1,020

a. Figures include ungraded students who are enrolled in school for special education and students who cannot be assigned to a grade because of the nature of their conditions; Prekindergarten refers to 3- and 4-year-old minors receiving special education.
b. Enrollment numbers have been rounded to two significant figures; totals to three significant figures.
c. Source: DIRS 157146-NDE (2001, all).
d. Source: DIRS 155820-NDE (2001, all).
e. Totals might not equal sums of values due to rounding.

Health Care. Health care services in the region of influence are concentrated in Clark County, particularly in the Las Vegas area. In 2000, Clark County had nine community hospitals (DIRS 156286-Medical Central Online 2001, all), including the newly opened 141-bed Siena campus of St. Rose Dominican (DIRS 156288-Babula 2000, all) and several specialized care facilities. Several major health care providers have proposed new hospitals or expansions of existing facilities and are awaiting various approval processes. Voters rejected a proposed Children's Hospital in June 2001. Although Nye County has one hospital in Tonopah, most people in the southern part of the county use local clinics or go to hospitals in Las Vegas. Lincoln County has one hospital in Caliente (DIRS 156286-Medical Central Online 2001, all). Table 3-29 lists hospital use in the region of influence.

Medical services are available at the Nevada Test Site for Exploratory Studies Facility personnel; these services include two paramedics and an ambulance in Area 25. Backup services are on call from other Test Site locations. In addition, the Nevada Test Site provides medical services for Yucca Mountain Project workers at a clinic in Mercury, which has no overnight capability. When patients need urgent care, the Yucca Mountain Project relies on the helicopter "Flight for Life" and "Air Life" operations from Las Vegas. In emergencies, Area 25 can call on Nellis Air Force Base or Nye County for help.

Law Enforcement. The Las Vegas Metropolitan Police Department is responsible for law enforcement in Clark County with the exceptions of the Cities of North Las Vegas, Henderson, Boulder City, and Mesquite, which have their own police departments. The Las Vegas police department is the largest law enforcement agency in Nevada; in 2001, it had about 2,620 employees including 1,750 commissioned officers; a ratio of about 2.5 employees or 1.6 commissioned officers per 1,000 residents. In 2000, the Nye County Sheriff Department had 113 employees, a ratio of 3.5 employees per 1,000 residents, and Lincoln County had 17 sheriff department employees serving an area of 27,500 square kilometers (10,600 square miles), a ratio of 4.0 employees per 1,000 residents. In comparison, the national officer-to-population ratio is 2.4 officers per 1,000 residents, (DIRS 148129-FBI 1996, pp. 1 to 3).

Table 3-29. Hospital use by county in the region of influence.[a]

County	1995[b]	1998	2000
Clark			
Population	1,000,000	1,260,000[c]	1,380,000[d]
Average number of beds	2,100	2,400[e]	2,600[f,g,h]
Beds per 1,000 residents	2.2	1.9[f]	1.9[e]
Patient-days	530,000	607,000[c]	N/A
Nye			
Population	24,000	29,700[c]	32,000[d]
Average number of beds	21	10[e]	42[f,g]
Beds per 1,000 residents	0.86	0.33[f]	1.3
Patient-days	1,900	560[e]	N/A
Lincoln			
Population	3,900	4,200[c]	4,200[d]
Average number of beds	4	4[e]	20[f,g]
Beds per 1,000 residents	1.0	0.95[f]	4.8
Patient-days	360	300[e]	N/A

a. All displayed numbers have been rounded to two or three significant figures.
b. Source: DIRS 103451-Rodefer et al. (1996, pp. 214 to 216).
c. Source: DIRS 153928-NDA (2000, all).
d. Source: DIRS 155872-Bureau of the Census (2000, County totals).
e. Average number of beds and patient days (DIRS 155910-State of Nevada 1999, all).
f. DIRS 156286-Medical Central Online (2001, all).
g. Actual, staffed number of beds.
h. DIRS 156288-Babula (2001, all).

Protection. A combination of fire departments provides protection in the region of influence; these include the Clark County, Las Vegas, and North Las Vegas fire departments and several other city, county, and military departments. In 2001, the Clark County Fire Department had about 500 paid and 390 volunteer firefighters. The Las Vegas Fire Department had 334 paid firefighters and the North Las Vegas Fire Department had 259 firefighters. In 2001, Nye County and Lincoln County met fire suppression needs with volunteers from the individual communities in the counties. The national average is 4.1 firefighters (paid and volunteer) per 1,000 residents.

3.1.8 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The public health and safety region of influence consists of the number of persons residing within an 80-kilometer (50-mile) radius of the repository site at the end of site characterization. The estimated population in 2000 is about 34,000, which could grow to an estimated 76,000 by 2035. Both the population estimate for 2000 and the projection for 2035 are based on the State Demographer and Local Agencies' Baseline as described in Section 3.1.7, and are distributed over the 80-kilometer (50-mile) radius as shown in Figure 3-25. The region of influence includes parts of Nye, Clark, Lincoln, and Esmeralda Counties in Nevada, as well as Inyo County in California (Figure 3-25). Potentially affected workers include those at the repository site and at nearby Nevada Test Site facilities. This section describes the existing radiation environment and the baseline cancer incidence in the region of influence. Unless otherwise noted, the *Environmental Baseline File for Human Health* (DIRS 104544-CRWMS M&O 1999, all) is the basis of the information in this section.

Section 3.1.8.1 describes the various radiation sources that make up the radiation environment.
Section 3.1.8.2 describes the existing radiation environment in the Yucca Mountain region.
Section 3.1.8.3 describes the health-related mineral issues encountered during site characterization activities. Section 3.1.8.4 describes the worker industrial safety experienced from site characterization activities.

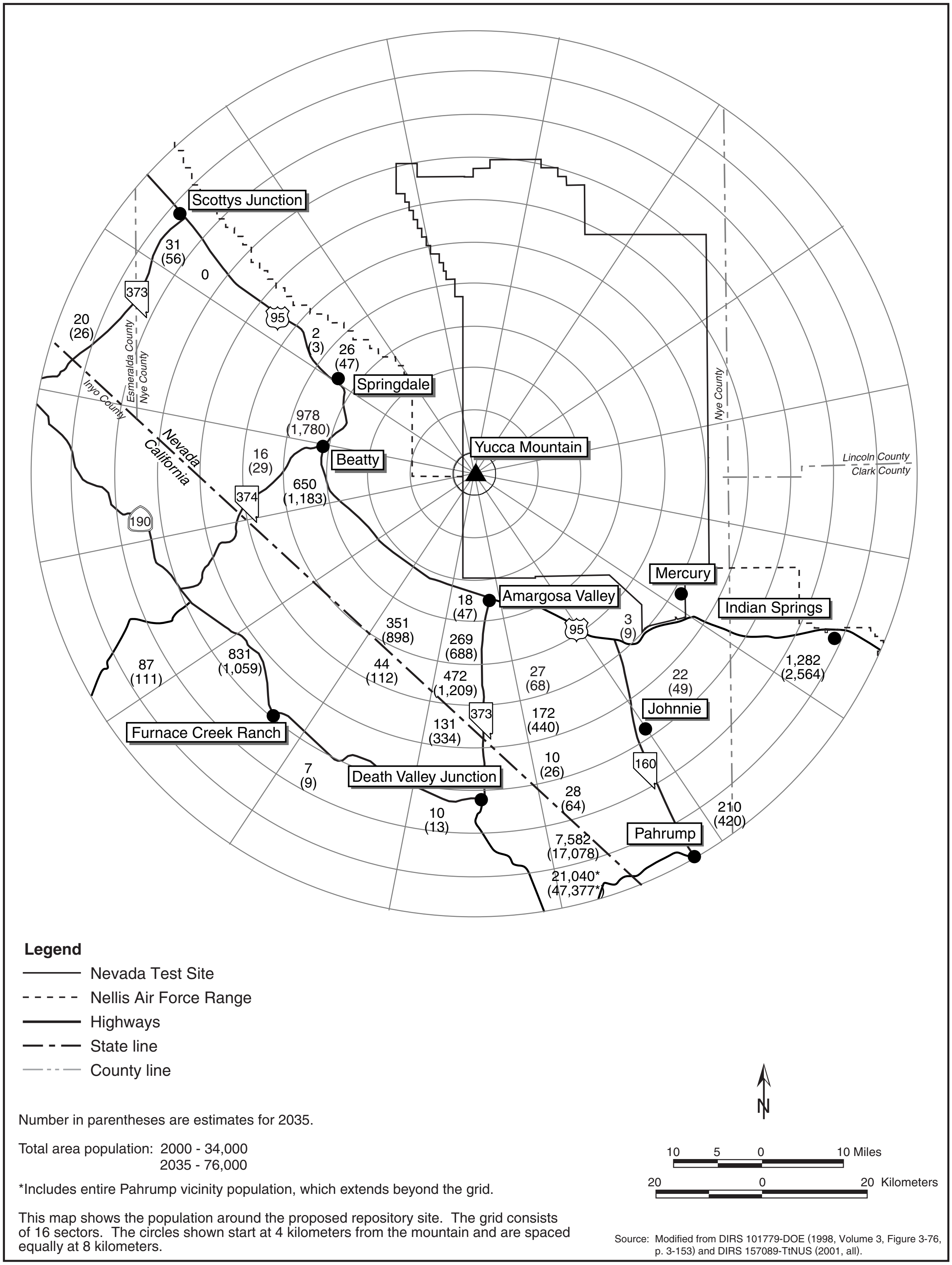

Figure 3-25. Population distribution within 80 kilometers (50 miles) of the proposed repository site, 2000 estimate and 2035 projection (in parentheses), based on the State Demographer and Local Agencies' Baseline.

3.1.8.1 Radiation Sources in the Environment

Types of Radiation. There are ambient levels of radiation at and around the site of the proposed repository just as there are around the world. All people are inevitably exposed to the three sources of *ionizing radiation*: those of *natural* origin unaffected by human activities, those of natural origin but affected by human activities (called *enhanced natural* sources), and *manmade* sources. Natural sources (natural background radiation) include *cosmic radiation* from space, *cosmogenic radionuclides* produced when cosmic radiation interacts with matter in the atmosphere or ground, and naturally occurring, long-lived primordial radionuclides in the Earth's mantle. Enhanced natural sources include those that can increase exposure as a result of human actions, deliberate or otherwise. For example, a mill tailings pile from a uranium extraction process probably would contain concentrated levels of naturally occurring radionuclides. A variety of radiation exposures, generally smaller than those caused by natural sources, result from manmade sources including nuclear medicine, medical *X-rays*, and consumer products.

Natural background radiation is the largest contributor to the average radiation dose of individuals. The natural occurrence of cosmic radiation, cosmogenic radionuclides, and primordial radionuclides varies throughout the world depending on such factors as altitude and geology. External radiation comes from all three of these natural sources, but cosmic radiation and radiation from primordial radionuclides are the largest dose contributors. Cosmic radiation consists of charged particles (primarily protons from extraterrestrial sources) that have sufficiently high energies to generate secondary particles that have direct and indirect ionizing properties. The three main primordial radionuclide contributors to external terrestrial gamma radiation are potassium-40 and the members of the thorium and uranium decay series. Most external terrestrial gamma radiation comes from the top 20 centimeters (8 inches) of soil, with a small contribution from airborne radon decay products. Although of smaller importance to natural external dose than the other two mechanisms, two cosmogenic radionuclides, sodium-22 and beryllium-7, produce quantifiable external doses in humans.

Internal radiation dose from natural sources comes primarily from the primordial radionuclides and their decay products. The largest individual source of internal dose comes from the inhalation of radon-222 and its decay products, which are all members of the uranium-238 decay series. This exposure comes mainly from inhalation of these radionuclides in indoor air, coming from the soil underneath buildings. All of the primordial radionuclides are in the body in various concentrations, incorporated by ingesting or inhaling these radionuclides in air, water, and all types of food products. In addition, two cosmogenic radionuclides—tritium (hydrogen-3) and carbon-14—produce quantifiable internal doses. Table 3-30 lists estimated radiation doses from natural sources to individuals in the region of influence and other locations in the United States.

Effects of Radiation Exposure. The effect of radiation on people depends on the kind of radiation exposure (alpha and beta particles, and X-rays and gamma rays), the total amount of tissue exposed to radiation, and the duration of the exposure. The amount of radiant energy imparted to tissue from exposure to ionizing radiation is referred to as *absorbed dose*. The sum of the absorbed dose to each tissue, when multiplied by certain quality and weighting factors that take into account radiation quality and different sensitivities of the various tissues, is referred to as *effective dose equivalent* and is expressed in *rem*. The Code of Federal Regulations contains further discussion of DOE radiation protection standards and methods of dose assessment (10 CFR Part 835).

An individual can be exposed to radiation from outside or inside the body because radioactive materials can enter the body by ingestion or inhalation. External dose is different from internal dose in that it is delivered only during the actual time of exposure. An internal dose, however, continues to be delivered as long as the radioactive source is in the body (although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes usually decrease the *dose rate* with the passage of time).

TERMS USED IN RADIATION DOSE ASSESSMENT

Curie: A unit of radioactivity equal to 37 billion disintegrations per second; also a quantity of any nuclide or mixture of nuclides having 1 curie of radioactivity.

Picocurie per liter (or gram): A unit of concentration measure describing the amount of radioactivity (in picocuries) in a volume (or mass) of a given substance [typically, air or water (by volume) or soil (by mass)]. A picocurie is one one-trillionth of a curie.

Rad: The unit of absorbed radiation dose in terms of energy. One rad is equal to an absorbed dose of 100 ergs per gram.

Rem: The unit of effective dose equivalent from ionizing radiation to the human body. It is used to express the amount of radiation to which a person has been exposed. The effective dose equivalent in rem is equal to the absorbed dose in rad multiplied by quality and weighting factors that are necessary because biological effects can vary both by the type of radiation (even of the same deposited energy) and by the specific tissue exposed.

Total effective dose equivalent: Often generically referred to simply as dose, it is an expression of the radiation dose received by an individual from external radiation and from radionuclides internally deposited in the body. All doses presented in this document are in terms of total effective dose equivalent.

Latent cancer fatality: A death resulting from cancer that has been caused by exposure to ionizing radiation. There is typically a latent period between the time of radiation exposure and the time the cancer cells become active.

Table 3-30. Radiation exposure from natural sources (millirem per year).[a]

Source	Annual dose (effective dose equivalent)					
	U.S. average	Aiken[b]	Oak Ridge[c]	Las Vegas	Region of influence: Amargosa Valley	Region of influence: Beatty
Cosmic and cosmogenic	28	29	36	(d)	40	(d)
Terrestrial	28	24	51	89	56	150
Radon in homes (inhaled)[e]	200	200	200	200	200	200
In body	40	40	40	40	40	40
Totals[f]	***300***	***290***	***330***	***330***	***340***	***390***

a. Sources: DIRS 146592-Black and Townsend (1998, p. 4-31); DIRS 103208-DOE (1995, p. 4-211 and 4-394) DIRS 103207-DOE (1995, Figure 3-16); DIRS 101855-NCRP (1987, Section 2); DIRS 153135-DOE (1999, p. A-9).
b. Aiken, South Carolina, is the location of the DOE Savannah River Site.
c. Oak Ridge, Tennessee, is the location of the DOE Oak Ridge Reservation.
d. Included in the terrestrial source.
e. Value for radon is an average for the United States.
f. Totals might differ from sums due to rounding.

Radiation can cause a variety of adverse health effects in people. The following discussion is an overview of the method commonly used to estimate effects of radiation exposure; Appendix F contains more detailed information. At low doses, the most important adverse health effect for depicting the consequences of environmental and occupational radiation exposures (which are typically low doses) is the potential inducement of cancers that can lead to death in later years. This effect is referred to as *latent cancer fatalities* because the cancer can take years to develop and for death to occur, and might never actually be the cause of death.

The collective dose to an exposed population is calculated by summing the estimated doses received by each member of the exposed population. This is referred to as a *population dose*. The total population dose received by the exposed population is measured in *person-rem*. For example, if 1,000 people each received a dose of 0.001 rem, the population dose would be 1.0 person-rem (1,000 persons multiplied by 0.001 rem equals 1.0 person-rem). The same population dose (1.0 person-rem) would result if 500 people each received a dose of 0.002 rem (500 persons multiplied by 0.002 rem equals 1 person-rem).

The factor used in this EIS to relate a dose to its potential effect is 0.0004 latent cancer fatality per person-rem for workers and 0.0005 latent cancer fatality per person-rem for individuals among the general population (DIRS 101856-NCRP 1993, p. 3). The latter factor is slightly higher because some individuals in the public, such as infants, might be more sensitive to radiation than workers. These risk factors have also been endorsed by the International Commission on Radiological Protection, Nuclear Regulatory Commission, and National Council on Radiation Protection and Measurements. The Environmental Protection Agency recently published an age-specific risk factor of 0.000575 latent cancer fatality per person-rem (DIRS 153733-EPA 2000, Table 7.3, p. 179), which is discussed in Appendix F. Both the Agency and DOE recognize that there are large uncertainties associated with these risk factors. As a consequence, DOE believes that the 15-percent difference in these risk factors (between 0.0005 and 0.000575) is well within other uncertainties and would provide little additional information to the decisionmaking process supported by this document. For these reasons, in its National Environmental Policy Act documents, DOE has continued to use risk factors recommended by the International Commission on Radiological Protection.

These concepts can be used to estimate the effects of exposing a population to radiation. For example, if 100,000 people were each exposed only to background radiation (0.3 rem per year), 15 latent cancer fatalities could occur as a result of 1 year of exposure (100,000 persons multiplied by 0.3 rem per year multiplied by 0.0005 latent cancer fatality per person-rem equals 15 latent cancer fatalities).

Calculations of the number of latent cancer fatalities associated with radiation exposure do not normally yield whole numbers and, especially in environmental applications, can yield numbers less than 1.0. For example, if 100,000 people were each exposed to a total dose of only 1 millirem (0.001 rem), the population dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons multiplied by 0.001 rem multiplied by 0.0005 latent cancer fatality per person-rem equals 0.05 latent cancer fatality).

The *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people is 0.05. In most groups, nobody (zero people) would incur a latent cancer fatality from the 1-millirem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The average number of deaths over all the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 is 0.25). The most likely outcome is no latent cancer fatalities in these different groups.

To aid in decisionmaking, DOE has applied these same concepts in estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The probability of a latent cancer fatality corresponding to a single individual's exposure to 0.3 rem a year over a (presumed) 70-year lifetime is:

Probability of a latent cancer fatality = 1 person × 0.3 rem per year × 70 years
× 0.0005 latent cancer fatality per person-rem
= 0.011 probability of a latent cancer fatality.

Again, this should be interpreted in a statistical sense; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1-percent chance that the individual would incur a latent fatal cancer. For comparison purposes, statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer from all causes (DIRS 153066-Murphy 2000, p. 83).

3.1.8.2 Radiation Environment in the Yucca Mountain Region

Ambient radiation levels from cosmic and terrestrial sources at Yucca Mountain are higher than the U.S. average. The higher elevation at Yucca Mountain results in higher levels of cosmic radiation due to less shielding by the atmosphere. The U.S. average for cosmic, cosmogenic, and terrestrial radiation exposures is 56 millirem per year (Table 3-30). The exposures at the Yucca Mountain ridge and Yucca Mountain surface facilities are about 160 and 150 millirem per year, respectively. Moreover, there are higher amounts of naturally occurring radionuclides in the soil and parent rock of this region than in some other regions of the United States, which also results in higher radiation doses.

The surface environment, or soil, of Yucca Mountain contains the following naturally occurring radionuclides (DIRS 146183-CRWMS M&O 1996, all):

Radionuclide	Dry weight concentration (picocuries per gram)
Uranium-238	0.002 to 0.22
Radium-226	0.77 to 3.3
Thorium-232	0.17 to 0.92
Potassium-40	18 to 35

DOE measured external dose rates on the surface with thermoluminescent dosimeters at 64 to 127 millirem per year. This compares to an average annual dose from cosmic, cosmogenic, and terrestrial radiation in the Amargosa Valley of 96 millirem per year (Table 3-30).

With respect to the subsurface environment, the content of naturally occurring uranium and thorium in rock at Yucca Mountain has been measured at 2 to 6 and 15 to 35 milligrams per kilogram, respectively (DIRS 105946-Vaniman et al. 1996, Table 1-5; DIRS 155605-Bush, Bunker, and Spengler 1983, Table 1, pp. 4 to 7). The activity concentrations for uranium-238 are about 0.7 to 1.7 *picocurie* per gram, and for thorium-232 they are about 1.7 to 3.7 picocuries per gram. The activity concentrations of uranium and thorium decay products, including various isotopes of radium, should be in equilibrium in undisturbed rock and have the same activity concentration as the respective precursor radionuclide. The potassium content of the rock ranges from about 1 to 5 percent (DIRS 155605-Bush, Bunker, and Spengler 1983, Table 1, pp. 4 to 7). Because the natural abundance of radioactive potassium-40 is about 0.012 percent, the potassium-40 content of the rock ranges from about 1.4 to 5.9 milligrams per kilogram, an activity concentration of 10 to 41 picocuries per gram. Appendix F, Section F.1.1.6 discusses the range of background external radiation levels in the Exploratory Studies Facility. External exposure rates range from 0.014 to 0.038 millirem per hour and the median dose to a subsurface worker would be about 40 millirem per year.

The Yucca Mountain Project and the DOE Nevada Operations Office (in conjunction with the Environmental Protection Agency) conduct environmental surveillances around the Nevada Test Site. This monitoring has identified no radioactivity attributable to current operations at the Test Site. It did detect trace amounts of manmade radionuclides from worldwide nuclear testing in milk, game, and foods and in soil. Even though the monitoring has not detected ongoing releases to the environment related to the Test Site, DOE has made quantitative estimates of offsite doses from releases from past weapons testing activities at the Nevada Test Site (DIRS 155569-Townsend and Grossman 2000, pp. 7-1 to 7-4). DOE discusses estimates of radiation doses to the general population from past test site activities at the end of this section. Sources of ongoing releases at the Nevada Test Site include water containment ponds and contaminated soil resuspension. The estimated maximum annual radiation dose to a hypothetical individual in Springdale, Nevada [approximately 14 kilometers (9 miles) north of Beatty on U.S. 95], from airborne radioactivity is 0.12 millirem and 0.38 person-rem to the population within 80 kilometers (50 miles) of Nevada Test Site airborne emission sources. The maximum hypothetical-individual dose, which is about 1 percent of the 10-millirem-per-year dose limit that the Environmental Protection Agency established for a member of the public from emissions to the air from manmade sources (40 CFR Part 61), is conservative because data from offsite surveillance do not support doses of this magnitude.

Workers in the Exploratory Studies Facility can inhale naturally occurring radon-222 (a radioactive *noble* gas that is a decay product of naturally occurring uranium in rock) and its radioactive decay products. Radon concentration measurements during working hours, at a location representative of repository conditions, ranged from about 0.24 to 65 picocuries per liter (5th to 95th percentile), with a median concentration of about 13 to 17 picocuries per liter (DIRS 156114-Carl 2001, all). The median annual dose to Exploratory Studies Facility workers from inhalation of radon and decay products underground was estimated to be about 15 millirem, with an average of about 40 millirem and range from 0 to 180 millirem (5th to 95th percentile) (DIRS 156118-Gonzalez 2001, all). Appendix F, Section F.1.1.6, contains additional information on the estimated underground dose to *involved workers* from radon.

Workers in the Exploratory Studies Facility are also exposed to external gamma radiation from radon decay products and other naturally occurring radionuclides. Ambient radiation monitoring in this facility indicated a dose rate from background sources of radionuclides in the drift walls of about 0.014 to 0.038 millirem per hour, which would be about 50 millirem per year for a 2000-hour work year (see Appendix F, Section F.1.1.6).

Naturally occurring radon-222 and decay products are released from the Exploratory Studies Facility in the exhaust ventilation air. The estimated annual release of radon and decay products is about 80 curies. The estimated annual dose to an individual 20 kilometers (12 miles) south of the repository is less than 0.1 millirem. The estimated annual dose to the population within 80 kilometers (50 miles) is about 10 person-rem. These doses are small percentages of the dose from natural sources shown in Table 3-30. Appendix G contains additional information on the estimated releases of radon from the repository.

Effects from Past Nevada Test Site Weapons Testing. The history of the testing of nuclear weapons can be broadly divided into two eras, the era in which testing was predominantly performed above ground (1951 to 1961) and the era in which testing was performed predominantly underground (1961 to 1992). Since 1992, there has been a moratorium on nuclear testing. DOE described the activities at the Nevada Test Site in a previous NEPA document, the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all).

Radiation doses to the population surrounding the Nevada Test Site have been the subject of several reports since the inception of the nuclear weapons testing program. For example, the National Council on Radiation Protection and Measurements published estimates of effective dose equivalents in its Publication 93 (DIRS 101855-NCRP 1987, all), in which it reported an average dose commitment to each individual in the United States from all weapons testing of approximately 250 millirem received up through 2000 with very little received thereafter from deposition in the body.

A more recent report prepared by the National Cancer Institute (DIRS 152469-Institute of Medicine and National Research Council 1999, all) evaluated doses to the thyroid glands of individuals from iodine-131 but did not estimate doses from other radionuclides. That report calculated thyroid doses for each series of nuclear weapons tests that had occurred and concluded that approximately 98 percent of the dose to the population due to iodine-131 deposition in the thyroid gland was from the atmospheric weapons testing, with approximately 2 percent due to underground testing.

The calculated average dose to the thyroid gland of individuals in Nevada ranged from 0.5 *rad* to 5.0 rad (which is close to 0.5 rem to 5.0 rem) for residents who lived in the area during all the tests. The

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National Cancer Institute further estimated an exposed population of 213,000 for iodine-131 exposure. The majority of that exposed population resided outside the region of influence evaluated in this EIS at the time of their exposure.

As discussed by the National Council on Radiation Protection and Measurements (DIRS 101855-NCRP 1987, all), because of the time that has elapsed since the occurrence of atmospheric nuclear weapons testing, much of the radioactivity in the environment with the potential to cause appreciable radiation dose has undergone decay. Therefore, individuals with the greatest potential for appreciable radiation doses from weapons testing would be those who were born before the 1960s, with less potential for those born later.

3.1.8.3 Health-Related Mineral Issues Identified During Site Characterization

Certain minerals known to present a potential risk to worker health are present in the volcanic rocks at Yucca Mountain (DIRS 101779-DOE 1998, Volume 1, pp. 2-24 and 2-25). The risks are generally related to potential exposures caused by inhalation of airborne particulates (dust). Some of the minerals represent a hazard commonly associated with underground construction, whereas others are rare and less well known.

Crystalline silica (silicon dioxide) comes in several forms—among them quartz, tridymite, and cristobalite. Inhaling silica dust causes a disease called *silicosis* that damages an area of the lungs called the air sac (alveoli) (DIRS 103243-EPA 1996, all). The presence of silica dust in the alveoli causes a defensive reaction that results in the formation of scar tissue in the lungs. This scar tissue can reduce overall lung capacity.

DOE typically performs evaluations of exposure to crystalline silica at Yucca Mountain for cristobalite that encompass potential impacts from exposure to other forms of crystalline silica. The repository host rock has a cristobalite content ranging from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). The American Conference of Governmental Industrial Hygienists has established Threshold Limit Values for various forms of crystalline silica (DIRS 103070-ACGIH 1999, p. 61). These limits are based on an 8-hour day and 40-hour week and, therefore, could be exceeded for a short period—as long as the average time spent by a worker is below the limit. The Threshold Limit Values for respirable cristobalite dust and quartz dust are 0.05 and 0.1 milligram per cubic meter, respectively. In addition, crystalline silica has been listed by the World Health Organization as a *carcinogen* (DIRS 100046-IARC 1997, p. 41).

Normal underground mechanical excavation produces dust when the rock is broken loose from the face. Dust is also generated when the broken rock is transferred to railcars or conveyors, or a storage pile. Dust can also be generated by wind erosion of excavated rock storage piles. Excavation activities during site characterization have caused exceedances of crystalline silica Threshold Limit Values at specific work locations. Workers at these locations were required to wear respirators. DOE will use the experience gained during Exploratory Studies Facility activities to design engineering controls to minimize future exposures.

Erionite is an uncommon zeolite mineral that the International Agency for Research on Cancer recognized as a human carcinogen in 1987; at Yucca Mountain, it occurs primarily in the basal vitrophyre of the Topopah Spring tuff and in isolated zones of the Tiva Canyon tuff (see Section 3.1.3). Even at low concentrations erionite is believed to be a potent carcinogen capable of causing mesothelioma, a form of lung cancer. As a result of its apparent carcinogenicity, erionite could pose a risk if encountered in quantity during underground construction, even with standard modern construction practices. Because erionite appears to be absent or rare at the proposed repository depth and location, most repository operations should not be affected. However, repository workers would take precautions (for example, dust suppression, air filters, personal protective gear) during construction when penetrating horizons in which erionite could occur, such as in the basal vitrophyre of the Topopah Spring tuff.

A number of other minerals present at Yucca Mountain might have associated health risks if prolonged exposures occur; however, there is no evidence suggesting a link to cancer. Therefore, the International Agency for Research on Cancer has ranked these substances not classifiable (DIRS 100046-IARC 1997, all). Some of the minerals identified and considered in establishing health and safety practices for potential repository operations include the zeolite group minerals mordenite (which is fibrous and similar in some respects to erionite), clinoptilolite, heulandite, and phillipsite. Because there is no known risk associated with the other zeolite minerals, and because they occur primarily in nonwelded units below the repository horizon, they probably do not represent a large risk. The measures implemented to mitigate risk from silica (for example, dust suppression, air filters, personal protective gear) should also protect workers from exposure to other minerals.

3.1.8.4 Industrial Health and Safety Impacts During Construction of the Exploratory Studies Facility

During Yucca Mountain site characterization activities, health and safety impacts to workers have resulted from common industrial hazards (such as tripping and falling). The categories of worker impacts include total *recordable* incidents, lost workdays, and fatalities. Recordable incidents or cases are occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) *lost workday cases* (nonfatal), and (3) incidents that result in the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Site characterization activities at Yucca Mountain have had no involved worker fatalities. DOE has compiled statistics for the other types of health and safety impacts in accordance with the regulations of the Occupational Safety and Health Administration (29 CFR Part 1904) (see Appendix F, Section F.2). These statistics cover the 30-month period from the fourth quarter of 1994 through the first quarter of 1997. DOE selected this period because there was high onsite work activity in which the tunnel-boring machine was in operation in the Exploratory Studies Facility. DOE expects this condition to be characteristic of the types of activities that would occur during the construction of the surface facilities and the development of the emplacement drifts. Table 3-31 lists the industrial health and safety loss statistics for industry, general construction, general mining, and the Yucca Mountain site.

Table 3-31. Comparison of health and safety statistics for mining activities from the Bureau of Labor Statistics to those for Yucca Mountain during excavation of the Exploratory Studies Facility.[a]

Statistic	Total industry[b]	General construction[b]	General mining[b]	Yucca Mountain experience for involved workers[c]
Total recordable cases rate	7.1	9.5	5.9	6.8
Lost workday cases rate	3.3	4.4	3.7	4.8
Fatality rate	Not available	Not available	Not available	0.0[d]

a. Statistics based on 100 full-time equivalent work years or 200,000 worker hours.
b. Source: DIRS 148091-BLS (1998, all).
c. Source: Appendix F, Section F.2.
d. There have been no fatalities on the Yucca Mountain Project. However, the fatality rate obtained from the entire DOE CAIRS database for industrial activities is 0.0029 per 100 full-time equivalent work years.

3.1.9 NOISE AND VIBRATION

The region of influence for noise includes existing residences in the Yucca Mountain region and at the approximate boundary of the analyzed land withdrawal area. Noise comes from either natural or manmade sources. DOE has evaluated existing noise conditions in the Yucca Mountain region and has compiled the detected ranges of noise levels at different locations under differing conditions.

3.1.9.1 Noise Sources and Levels

Yucca Mountain is in a quiet desert environment where natural phenomena such as wind, rain, and wildlife account for most background noise. The acoustic environment is typical of other desert environments where average day-night sound-level values range from 22 decibels on calm days to 38 decibels on windy days (DIRS 102224-Brattstrom and Bondello 1983, p. 170).

Manmade noise occurs periodically in the area as vehicles travel to and from Yucca Mountain, from site characterization activities at the operations areas, and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain operations areas were consistent with noise levels associated with industrial operations [sound levels from 44 to 72 decibels (A-weighted)] (DIRS 101531-Brown-Buntin 1997, pp. 4-6). Table 3-32 lists estimated sound-level values for Yucca Mountain, nearby communities and cities, and other environments.

Table 3-32. Estimated sound levels in southern Nevada environments.[a]

Environment	Sound level[b] (decibels)
Calm day at Yucca Mountain	22
Windy day at Yucca Mountain	38
Rural communities (Panaca, Hadley, Rachel, Crystal Springs, Ash Springs, Cactus Springs, Alamo, Jean, Goodsprings, Sandy)	40 - 47
Small towns or rural communities along busy highways (Beatty, Indian Springs, Pahrump, Amargosa Valley, Caliente, Tonopah, Goldfield, Mercury) and at the intersection of proposed transportation routes to Yucca Mountain	45 - 55
Suburban parts of Las Vegas	52 - 60
Urban parts of Las Vegas	56 - 66
Dense urban parts of Las Vegas with heavy traffic	64 - 74
Under flight path at McCarran International Airport (0.8 to 1.6 kilometers[c] from runway)	78 - 88

a. Source: Modified from DIRS 101821-EPA (1974, p. 14); DIRS 102224-Brattstrom and Bondello (1983, p. 170).
b. Day-night average sound level.
c. About 0.5 to 1 mile.

3.1.9.2 Regulatory Standards

With the exception of prohibiting nuisance noise, neither the State of Nevada nor local governments have established numerical noise standards. Nevertheless, many Federal agencies use average day-night sound levels as guidelines for land-use compatibility and to assess the impacts of noise on people. Many agencies, including the Environmental Protection Agency, recognize an average day-night sound level of 55 decibels (A-weighted) as an outdoor goal for protecting public health and welfare in residential areas (DIRS 101821-EPA 1974, p. 3). This noise level, which has been established by scientific consensus, is not a regulatory criterion in Nevada, and could protect against activity interference and annoyance. While Nevada does not have a noise code, daytime and nighttime noise standards adopted by Washington State (WAC-173-60 and 70) for residential and commercial areas can serve as benchmarks for evaluating potential impacts based on land use. These benchmarks are 60 decibels for residential use (nighttime reduction to 50 decibels), 65 decibels for light commercial, and 70 decibels for industrial zones. As required, DOE monitors noise levels in worker areas, and a hearing protection program has been in place during site characterization. Hearing protection is used as a supplement to engineering controls, which are the primary method of noise suppression.

Sound levels that cause annoyance in people vary greatly by individual and background conditions. However, the threshold for hearing hazard, which depends on the frequency of the sound, ranges from around 65 decibels at a frequency of 4,000 hertz to about 88 decibels at frequencies of 125 and 8,000 hertz (DIRS 155778-Melnick 1998, Vol. 12, p. 18). These threshold levels assume continuous exposure for periods of hours. High risk for hearing loss occurs at 120 decibels and can result from short-term exposure of seconds to minutes. Ground transportation activities such as those associated with the Proposed Action (either rail or heavy-haul trucks) would not propagate noise levels of this magnitude to the environment.

3.1.9.3 Vibration

Ground vibration is an element of environmental assessment. Many natural phenomena (wave action on beaches, strong winds, earthquakes, etc.) as well as human activities (construction, transportation, military activities, etc.) can contribute to ground vibration. As a consequence, there is a component of background vibration that exists, generally higher in large cities than in rural communities, and lower in areas more distant from human activities. This vibration component can be altered by a change in site activities.

There are two measurements for evaluating ground vibration: peak particle velocity and root-mean-square velocity (DIRS 155547-HMMH 1995, p. 7-3). *Peak particle velocity* is the maximum instantaneous positive or negative peak of the vibration signal, measured as a distance per time (such as millimeters or inches per second). This measurement has been used historically to evaluate "shock"-wave type vibrations from actions like blasting, pile driving, and mining activities, and their relationship to building damage. The root-mean-square level is an average or smoothed vibration amplitude, commonly measured over 1-second intervals. It is expressed on a log scale in decibels (VdB) referenced to 0.000001 (10^{-6}) inch per second and is not to be confused with noise decibels. It is more suitable for addressing human annoyance and characterizing background vibration conditions because it better represents the response time of humans to ground vibration signals.

A typical background level of ground vibration is 52 VdB, and the human threshold for the perception of ground vibration is 65 VdB (DIRS 148155-Hanson, Saurenman, and Towers 1998, p. 46.17). There are three ground vibration impacts of general concern: human annoyance, damage to buildings, and interference to vibration-sensitive activities. Three categories of buildings and associated human activities have been established for the assessment of annoyance or interference impacts from ground vibration (DIRS 155547-HMMH 1995, pp. 8-2 to 8-3). Table 3-33 lists these categories along with associated benchmark vibration levels at which adverse impacts might be likely. An important element of the criteria for human disturbance is the frequency of distinct ground vibration events; the more events, the higher the likelihood of annoyance. Most environmental evaluations have focused on mass transit, where there is a high frequency of events.

Vibration criteria for structural damage in fragile or extremely fragile buildings have separate structural criteria based on peak particle velocity and an approximation of VdB that have been segregated into impulse and rail impacts. Table 3-33 lists these criteria. Building damage from ground vibration, which is rare, is associated with vibration levels that are unpleasant or disturbing long before there is any possibility of damage to the building.

Background levels of ground vibration at the Yucca Mountain site are low. Other than site characterization-related activities, there is basically a lack of the classical, manmade sources of ground vibration impacts; that is, impacts from pile driving, heavy earth-moving equipment (particularly equipment with metal tracks), and blasting.

NOISE MEASUREMENT

What are *sound* and *noise*?

When an object vibrates it possesses energy, some of which transfers to the air, causing the air molecules to vibrate. The disturbance in the air travels to the eardrum, causing it to vibrate at the same frequency. The ear and brain translate the vibration of the eardrum to what we call *sound*. *Noise* is simply unwanted sound.

How is sound measured?

The human ear responds to sound pressures over an extremely wide range of values. The range of sounds people normally experience extends from low to high pressures by a factor of 1 million. Accordingly, scientists have devised a special scale to measure sound. The term decibel (abbreviated dB), borrowed from electrical engineering, is the unit commonly used.

Another common sound measurement is the A-weighted sound level, denoted as dBA. The A-weighting accounts for the fact that the human ear responds more effectively to some pitches than others. Higher pitches receive less weighting than lower ones. Most of the sound levels provided in this EIS are A-weighted; however, some are in decibels due to lack of information on the frequency spectrum of the sound. The scale to the right provides common references to sound on the A-weighted sound-level scale.

Source: Modified from DIRS 103233-DOE (1999, p. 3-39)

TYPICAL A-WEIGHTED SOUND LEVELS

	DECIBELS	
50-horsepower siren (33 meters)[a]	140	
Jet takeoff (66 meters)	130	
Riveting machine[b]	120	Diesel motors
Cut-off saw Pneumatic peen hammer[b]	110	
Rock drill (16 meters) Textile weaving plant[b]	100	Outdoor public address system loudspeakers
Subway train (6.6 meters) Dump truck (16 meters) Pneumatic drill (16 meters)	90	Ventilation fans
Freight train (33 meters) Vacuum cleaner (3.3 meters)	80	Inside sports car (24 meters per second)[c]
Speech (0.33 meters) Passenger auto (16 meters)	70	
Large transformer (66 meters)	60	Near freeway (auto traffic) Large store Accounting office
	50	Private business office Light traffic (33 meters) Average residence
Soft whisper (13 centimeters)[d]	40	
	30	Studio (speech)
	20	Quiet
	10	
Threshold of hearing (youths)	0	

a. To convert meters to feet, multiply by 3.2808.
b. Operator's position.
c. 24 meters per second = about 50 miles per hour.
d. 13 centimeters = about 5 inches.

3.1.10 AESTHETICS

Visual resources, with nighttime darkness as a component, include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The physical features representing the region of influence for aesthetics are those found within the approximate boundary of the analyzed land withdrawal area. Sections 3.1.3 and 3.1.5 describe the geologic and biological settings, respectively, at Yucca Mountain.

The region surrounding Yucca Mountain consists of unpopulated to sparsely populated desert and rural lands. Because much of Yucca Mountain is on the Nevada Test Site and Nellis Air Force Range with restricted public access, public visibility is limited to portions of U.S. Highway 95 near Amargosa Valley.

Table 3-33. Benchmark ground vibration criteria for buildings and human annoyance.[a]

Category	Frequent events (>70/day) VdB[b]	Infrequent events (<70/day) PPV (in/sec)[c]	Infrequent events (<70/day) VdB	Impact of concern
Annoyance or interference				
1. High sensitive buildings[d]	65	NA[e]	65	Sensitive equipment
2. Residential[f]	72	NA	80	Human disturbance
3. Institutional[g]	75	NA	83	Human disturbance
Structural damage				
Fragile buildings	NA	0.20	~100 (Impulse) 92 (Rail)	Structural damage
Extremely fragile buildings	NA	0.12	~95 (Impulse 88 (Rail)	Structural damage

a. Source: DIRS 155547-HMHH (1995, p. 8-3).
b. Root-mean-square velocity expressed in decibels - VdB - referenced to 10^{-6} inch per second.
c. Peak particle velocity in inches per second; to convert to millimeters per second, multiply by 25.4.
d. Buildings with vibration-sensitive equipment (for example, at research institutions and medical facilities).
e. NA = not applicable.
f. Homes or buildings where people sleep.
g. Schools, churches, and office buildings.

The Bureau of Land Management uses four visual resource classes in the management of public lands (DIRS 101505-BLM 1986, all). Classes I and II are the most valued, Class III is moderately valued, and Class IV is of least value. Visual resources fall into one of these management classes based on a combination of three factors: (1) scenic quality, (2) visual sensitivity, and (3) distance from travel routes or observation points (DIRS 101505-BLM 1986, all). There are three scenic quality classes in the Bureau of Land Management Visual Resource Management system. Class A includes areas that combine the most outstanding characteristics of each physical feature category. Class B includes areas in which there is a combination of some outstanding and some fairly common characteristics. Class C includes areas in which the characteristics are fairly common to the region. A visual sensitivity rating for an area is based on the number and types of users, special areas (natural areas, wilderness areas), public interest in the area, and adjacent land uses. Though a scenic quality rating (A, B, or C) is used in conjunction with visual sensitivity and distance zones (foreground, middleground, background, and seldom seen) to produce Visual Resource Management Classes, the scenic quality rating is often used independently to emphasize a visual resource within a management class area. For example, a Wilderness Study Area might have a Class A scenic rating and be in a Class II or III management area.

The Bureau of Land Management has not assigned a Visual Resource Management class to Yucca Mountain because the Nevada Test Site is not under the Bureau's jurisdiction. However, using the Bureau's method of determining scenic quality, DOE has evaluated the visual resources of the Yucca Mountain region from two observation points—one at Amargosa Valley on U.S. 95 and the other on the Nevada Test Site at a location that provides a clear view of the proposed repository site (DIRS 105002-CRWMS M&O 1999, all).

The visual assessment at both these locations concluded that the scenic quality classification of Yucca Mountain is C.

Nighttime darkness in the Yucca Mountain region is a valued component of the solitude experience sought by many individuals, and greatly enhances astronomy and stargazing activities. It is also felt to be one of the important scenic resources of the Death Valley National Park. Existing or potential sources of nighttime light in this area include the Towns of Beatty and Amargosa Valley that lie between Death Valley National Park and the Yucca Mountain site; the community of Pahrump slightly east of the Park; and Las Vegas farther to the east. Las Vegas is the largest source of nighttime light in the extended region; the glow of its lights is evident in the night sky at much farther distances than other city features.

BUREAU OF LAND MANAGEMENT VISUAL RESOURCE MANAGEMENT CLASS OBJECTIVES
(used in the management of public lands)

Class I	The objective of this class is to preserve the existing character of the landscape. This class provides for natural ecological changes; however, it does not preclude very limited management activity. The level of change to the characteristic landscape should be very low and must not attract attention.
Class II	The objective of this class is to retain the existing character of the landscape. The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.
Class III	The objective of this class is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape.
Class IV	The objective of this class is to provide for management activities that require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high. These management activities may dominate the view and be the major focus of viewer attention. However, every attempt should be made to minimize the impact of these activities through careful location, minimal disturbance, and repeating the basic elements.

Current lighting at the repository site is similar to or less than lighting at other work areas on the Nevada Test Site and represents a minor contribution to the area's sources of nighttime lighting.

3.1.11 UTILITIES, ENERGY, AND SITE SERVICES

DOE research into the current consumer demand for utilities and energy in the Yucca Mountain region has yielded information on water and power sources, use, and supply systems. The research included water treatment capabilities. The region of influence for potential impacts to utility and energy supplies consists of those public and private resources on which DOE would draw to support the Proposed Action, and which are in Clark, Lincoln, and Nye Counties in Nevada. Sections 3.1.11.1 and 3.1.11.2 contain information on current water and energy suppliers and consumer use. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Utilities, Energy, and Site Services* (DIRS 104988-CRWMS M&O 1999, all) is the basis of the information in this section.

3.1.11.1 Utilities

Water and sewer utilities in the region could be affected by the Proposed Action as a result of project-related increases in population and the associated increases in water demand and sewage production. DOE anticipates that the predominant project-related increase in population would occur in Clark County, with a smaller increase in Nye County (see Section 3.1.7).

Water. The Southern Nevada Water Authority supplies water to five communities in Clark County: Boulder City, Henderson, Las Vegas (including parts of unincorporated Clark County), Nellis Air Force

Base, and North Las Vegas. Eighty-five percent of the water supplied to the Las Vegas Valley comes from the Colorado River through Lake Mead; the remaining 15 percent comes from groundwater (Las Vegas Valley Hydrographic Area; DIRS 101923-SNWA 1997, p. 2). To meet growing water demands, the Water Authority is upgrading current facilities and installing new facilities, such as a second raw water intake at Lake Mead, a second water treatment facility, and additional pipelines and pumping stations.

In southern Nye County, where the repository would be, groundwater is the only source of water. In August 1996, a water supply and demand evaluation for southern Nye County, including Beatty, Amargosa Desert, and Pahrump, was performed (DIRS 101542-Buqo 1996, all). The evaluation indicated the Beatty (Oasis Valley Hydrographic Area) water utility would have difficulty meeting future water demands due not to a high growth rate but to falling well yields and poor water quality in some wells. It further predicted that existing pumping capacity would not be adequate to meet projected peak demands between 1997 and 2000, and one or more additional wells would be needed. Since the 1996 evaluation, Beatty has gained the use of another well (formerly used by the Bullfrog Mine), which has provided a capacity sufficient to meet water demand now and for the immediate future, even while ending the use of two wells with high fluoride (DIRS 156759-Davis 2001, all). In Amargosa Desert (Amargosa Desert Hydrographic Area), the current committed amount of groundwater appropriations (permits and certificates) is larger than the lower estimate of perennial yield for the applicable groundwater. However, historic pumping amounts have never been higher than the estimates of yield. In Pahrump (Pahrump Valley Hydrographic Area), the total groundwater pumped from the basin in 1995 was almost 30 million cubic meters (24,000 acre-feet). This is about 25 percent higher than the upper end of estimates of the basin's perennial yield, which range from 15 million cubic meters [12,000 acre-feet (DIRS 103406-NDWP 1992, Region 10)] to 23 million cubic meters [19,000 acre-feet (DIRS 101542-Buqo 1996, p. 17)]. Much of Pahrump's water consumption results from about 7,000 domestic water supply wells. Drilling continues at a rate of about 700 wells a year (DIRS 103099-Buqo 1999, p. 36) . Alternatives to address long-term water supply issues in Pahrump Valley include optimizing the locations of new wells, reducing per capita consumption, developing the carbonate aquifer, and importing water from other groundwater basins. Overall groundwater withdrawals in Nye County totaled about 93 million cubic meters (75,000 acre-feet) in 1995. The predominant use of this water was agriculture, accounting for 80 percent of the total; domestic use was responsible for only 7 percent of the total withdrawal (DIRS 104888-LeStrange 1997, Table 1).

Sewer. Wastewater treatment needs in the Las Vegas Valley are supported by three major wastewater treatment facilities: one operated by the City of Las Vegas (which also serves the City of North Las Vegas); one operated by the City of Henderson; and one operated by the Clark County Sanitation District. The County Sanitation District includes all the unincorporated areas in Clark County, and it provides services to several outlying communities including Blue Diamond, Laughlin, Overton, and Searchlight (DIRS 148106-Clark County Sanitation District 1999, all). However, its primary service area is the portion of the Las Vegas Valley south and east of the City of Las Vegas and extending to Henderson. There might be other small wastewater treatment units serving parts of Clark County outside the populous area of the Las Vegas Valley, but septic tank and drainage field systems provide the primary means of wastewater treatment in these outlying areas, particularly for private residences.

Southern Nye County does not have a metropolitan area or a sanitation district comparable to Clark County. Most communities in this area rely primarily on individual dwelling or small communal wastewater treatment systems, with the exception of Beatty, which has municipal sewer service. For example, Pahrump has no community-wide wastewater treatment system. Several wastewater treatment units serve parts of the town, such as the dairy and the jail, but most households have septic tank and drainage field systems. This is likely to be typical of the small communities in southern Nye County.

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3.1.11.2 Energy

Electric Power. Three different power distributors—Nevada Power Company, Valley Electric Association, Inc., and Lincoln County Power District No. 1—supply electric power in the region of influence.

Nevada Power Company supplies electricity to southern Nevada in a corridor from southern Clark County, including Las Vegas, North Las Vegas, Henderson, and Laughlin, to the Nevada Test Site in Nye County. In 2000, the power sources were about 50 percent company-generated and about 50 percent purchased power. In 2000, Nevada Power Company sold 17.9 million megawatt-hours to its 620,000 customers, and the peak load was the highest ever at about 4,300 megawatts. Nevada Power Company has an annual customer growth rate of about 6 percent. To keep pace with demands for electricity, each year Nevada Power must build more substations and transmission and distribution facilities; in 2001 to 2003, it plans to invest about $320 million in such equipment (DIRS 155864-NPC 2000, all). Recent energy concerns have caused the forecasting of supply and demand to be much more uncertain than in the past, as reflected in recent planning documents released by Nevada Power Company. Nevada Power Company merged with Sierra Pacific Resources in July 1999 (DIRS 153929-NPC 1999, all). Sierra Pacific Resources is the holding company for the Sierra Pacific Power Company, which provides electric power to much of northern Nevada and the Lake Tahoe area.

The Valley Electric Association is a nonprofit cooperative that distributes power to southern Nye County, including Pahrump Valley, Amargosa Valley, Beatty, and the Nevada Test Site. The Western Area Power Administration allocates Valley Electric a portion of the lower cost hydroelectric power from the Colorado River dams. The private power market supplies the supplemental power necessary to meet the needs of the members. Since 1995, the amount of power available in the marketplace has been abundant. The amount of energy that Valley Electric sells annually to its members almost tripled in the 11 years from 1985 through 1995. In 1995, Valley Electric sold about 300 million kilowatt-hours to its 8,600 members (DIRS 101846-McCauley 1997, pp. 54 and 55). To meet the power demands of its members, Valley Electric has built a new 230-kilovolt transmission line from Las Vegas to Pahrump and plans to install three new substations in Pahrump.

At present, two commercial utility companies own transmission lines that supply electricity to the Nevada Test Site (Figure 3-26). The electric power for the Yucca Mountain Project in Area 25 comes through the Nevada Test Site power grid. The Test Site buys power at 138 kilovolts at the Mercury Switch Station and at the Jackass Flats Substation. The 138-kilovolt system at the Test Site has nine substations, one switching center, and one tap station, which are connected by approximately 210 kilometers (130 miles) of transmission line. A 138-kilovolt line owned by Nevada Power Company connects the Mercury Switch Station to the Jackass Flats substation, which reduces the power and transmits it to the Field Operations Center and nearby buildings in Area 25 that support the Yucca Mountain Project. A Valley Electric Association 138-kilovolt line also provides power to the Jackass Flats Substation. From the Jackass Flats substation, a 138-kilovolt line feeds the Canyon Substation in Area 25, which provides power to the Exploratory Studies Facility. The Canyon Substation reduces the voltage from 138 to 69 kilovolts, with a capacity of 10 megawatts, and transmits it to the Yucca Mountain substation at the Exploratory Studies Facility.

The capacity of the Nevada Test Site grid is 72 megawatts. Since 1990, the peak load was about 37 megawatts and occurred in January 1992 (DIRS 104955-LeStrange 1997, p. 1).

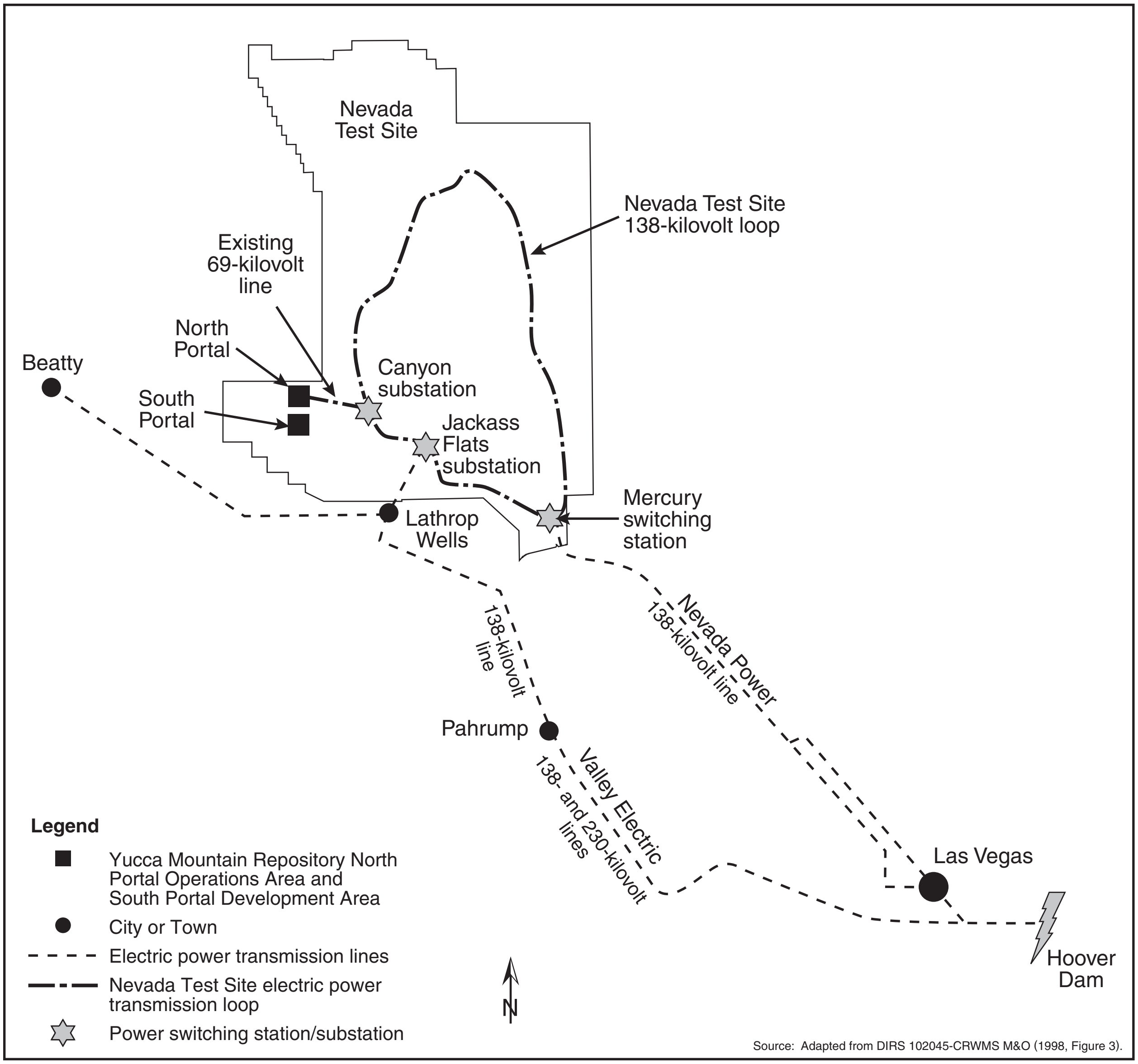

Figure 3-26. Existing Nevada Test Site electric power supply.

Table 3-34 lists the combined historic and projected electricity use for the Exploratory Studies Facility and the Field Operations Center for 1995 through 2000. The Exploratory Studies Facility consumed about 70 percent of the listed amounts (DIRS 104955-LeStrange 1997, all). Annual power use and peak demand at the Exploratory Studies Facility would probably decline and stabilize at a lower level than the 1997 use rates because site activity would decline until repository construction began in 2005. Historically, from 1995 through 1997 Exploratory Studies Facility use has accounted for about 15 percent to 20 percent of the electric power used by all of the Nevada Test Site (DIRS 104988-CRWMS M&O 1999, Table 2, p. 6).

Fossil Fuel. The fossil fuels that DOE has used at the Exploratory Studies Facility are heating oil, propane, diesel, gasoline, and kerosene. Natural gas, coal, and jet fuel have not been used. In 1996, site activities consumed about 1.02 million liters (270,000 gallons) of heating oil and diesel fuel and about 65,000 liters (17,000 gallons) of propane; in 1997, they consumed slightly less than 1 million liters (264,000 gallons) of heating oil and diesel fuels. The amounts of gasoline and kerosene used at the

Table 3-34. Electric power use for the Exploratory Studies Facility and Field Operations Center.[a,b]

Fiscal Year	Power use	
	Consumption (megawatt-hours)	Peak (megawatts)
1995	9,800	3.5
1996	19,000	4.9
1997	23,000	5.3
1998[c]	21,000	4.2
1999[c]	17,000	4.2
2000[c]	8,700	4.2

a. Source: DIRS 104988-CRWMS M&O (1999, Table 2, p. 6)
b. Before 1995, Yucca Mountain Project power was not metered separately.
c. Estimated.

Exploratory Studies Facility were very small in those years. Fossil-fuel supplies are delivered to the Nevada Test Site and the Exploratory Studies Facility by truck from readily available supplies in southern Nevada.

3.1.11.3 Site Services

DOE has established an existing support infrastructure to provide emergency services to the Exploratory Studies Facility. The Yucca Mountain Project *Emergency Management Plan* (DIRS 102618-YMP 1998, all) describes emergency planning, preparedness, and response. The project cooperates with the Nevada Test Site in such areas as training and emergency drills and exercises to provide full emergency preparedness capability to the site. In addition, the project trains and maintains an underground rescue team. The Nevada Test Site security program is responsible for project security, with enforcement provided by a contractor following direction from DOE. The Nye County Sheriff's Department provides law enforcement and officers for Yucca Mountain site patrol. Nevada Test Site personnel and equipment support fire protection and medical services. Medical services are provided through the Nevada Test Site by two paramedics and an ambulance stationed in Area 25 with backup from other Test Site locations. The Yucca Mountain staff uses a medical clinic with outpatient capability at Mercury. Urgent medical transport is provided by the "Flight for Life" and "Air Life" programs from Las Vegas. Nellis Air Force Base and Nye County also provide emergency support.

3.1.12 WASTE AND HAZARDOUS MATERIALS

The region of influence for waste and hazardous materials consists of on- and offsite areas, including landfills and radioactive waste processing and disposal sites, in which DOE would dispose of waste generated under the Proposed Action. This region of influence can be described, to a large extent, through considering the manner in which waste has been managed during the current Yucca Mountain activities.

The Yucca Mountain Site Characterization Project developed its waste management systems to handle the waste and recyclable material generated by its activities. This material includes nonhazardous solid waste; construction debris; hazardous waste; recyclables such as lead-acid batteries, used oil, metals, paper, and cardboard (DIRS 152012-McCann 2000, pp. 1 to 6); sanitary sewage; and wastewater. It does not include low-level radioactive or mixed wastes. DOE uses landfills to dispose of solid waste and construction debris; accumulates and consolidates hazardous waste, then transports it off the site for treatment and disposal; treats and reuses wastewater; and treats and disposes of *sanitary waste*. In most categories of waste, especially solid waste, some types of material can be recycled or reused. DOE has processes in place to ensure that it collects the material and recycles it as appropriate.

3.1.12.1 Solid Waste

DOE disposes of Yucca Mountain Site Characterization Project solid waste and construction debris in landfills in Areas 23 and 9, respectively, on the Nevada Test Site. The Area 23 landfill has a capacity of 450,000 cubic meters (16 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37) and a 100-year estimated life (DIRS 101803-DOE 1995, p. 9). The Area 9 landfill, which is in Crater U-10C, is an open circular pit with steep, almost vertical sides formed as a result of an underground nuclear test. The Area 9 landfill has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37) and an estimated 70-year operational life (DIRS 101803-DOE 1995, p. 8). The environmental impact statement for the Nevada Test Site describes these landfills (DIRS 101811-DOE 1996, p. 4-37). DOE disposes of Yucca Mountain Site Characterization Project oil-contaminated debris from maintenance activities at the industrial landfill at Apex, Nevada, using an environmental company for transport and disposal. The Apex facility is a multilined landfill with on- and offsite monitoring in compliance with State of Nevada requirements (DIRS 152012-McCann 2000, p. 3).

DOE recycles as many materials as feasible from its site characterization activities. The *Waste Minimization and Pollution Prevention Awareness Plan, Approved* (DIRS 103203-YMP 1997, all) governs recycling and other waste minimization activities. At present, a Nevada Test Site contractor collects paper, cardboard, aluminum cans, and scrap metal and recycles it. For such recyclables as oils, solvents, coolants, lead-acid batteries, and oil-contaminated soils, the Yucca Mountain Site Characterization Project contracts directly with recycling services (DIRS 152012-McCann 2000, pp. 1 to 5).

Solid waste generated by the construction and operation of transportation facilities could be disposed of in offsite landfills. At present, there are 24 operating municipal solid waste landfills in Nevada (DIRS 155563-NDEP 2001, all) with a combined capacity to accept 11,000 metric tons (12,000 tons) of waste per day. In 2000, about 3.5 million metric tons (3.9 million tons) of sanitary solid waste was disposed of in Nevada (DIRS 155565-NDEP 2001, Section 2.1). Eleven Nevada landfills accept industrial and special waste (DIRS 155563-NDEP 2001, all), which includes construction debris and other solid waste such as tires that have specific management requirements for permitted landfill disposal. The State's largest regional landfill accepts municipal and industrial waste and has a capacity of 6,300 metric tons (6,900 tons) per day (DIRS 155563-NDEP 2001, all). In 2000, about 750,000 metric tons (823,000 tons) of construction debris and about 83,000 metric tons (91,000 tons) of other wastes were disposed of in the State (DIRS 155565-NDEP 2001, Section 2.1).

3.1.12.2 Hazardous Waste

The Yucca Mountain Site Characterization Project is a small-quantity [less than 1,000 kilograms (2,200 pounds) a month] generator of hazardous waste. DOE accumulates hazardous wastes near their generation sources, consolidates them at a central location at the Yucca Mountain site, and ships them off the site for treatment and disposal. The hazardous waste accumulation areas are managed in accordance with Federal and State regulations. The waste is treated and disposed of off the site at a permitted treatment, storage, and disposal facility (DIRS 152012-McCann 2000, p. 6).

3.1.12.3 Wastewater

DOE uses a septic system to treat and dispose of sanitary sewage at the Yucca Mountain site (DIRS 102303-CRWMS M&O 1998, p. 15). The system design can handle a daily flow of about 76,000 liters (20,000 gallons) (DIRS 102599-CRWMS M&O 1998, p. 64).

At present, wastewater from tunneling operations and water from secondary containment (following rains) is processed through an oil-water separator, and the treated water is used for dust suppression in accordance with a State of Nevada permit (DIRS 152012-McCann 2000, p. 4). The oil is recycled with the other used oil generated by the project.

3.1.12.4 Existing Low-Level Radioactive Waste Disposal Capacity

The Nevada Test Site accepts low-level radioactive waste for disposal from approved generator sites. It has an estimated disposal capacity of 3.7 million cubic meters (130 million cubic feet). DOE estimates

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that a total of approximately 1.1 million cubic meters (39 million cubic feet) of low-level radioactive waste will be disposed of at the Test Site through 2070 (DIRS 155856-DOE 2000, Table 4-1, p. 4-2), not including repository-generated waste.

Commercial spent nuclear fuel generators and contractor-operated transportation facilities such as an intermodal transfer station would dispose of low-level radioactive waste in commercial facilities. Commercial disposal capacity for low-level radioactive wastes is available at three licensed facilities (DIRS 152583-NRC 2000, U.S. Low-Level Radioactive Waste Disposal Section).

3.1.12.5 Materials Management

DOE has programs and procedures in place to procure and manage hazardous and nonhazardous chemicals and materials (DIRS 104842-YMP 1996, all). By using these programs, the Department is able to minimize the number and quantities of hazardous chemicals and materials stored at the Yucca Mountain site and maintain appropriate storage facilities.

The chemical and material inventory report (DIRS 148107-Dixon 1999, pp. 4, 4a, and 5) for the Nevada State Fire Marshal's office lists 33 hazardous chemicals and materials. The Yucca Mountain Project holds many of these in small quantities, and it stores sulfuric acid in larger quantities [above the threshold planning quantity of about 450 kilograms (1,000 pounds) that requires emergency planning]. Most of the sulfuric acid is in lead-acid batteries (DIRS 148107-Dixon 1999, all). In addition, the Yucca Mountain Site Characterization Project stores the following hazardous chemicals in large amounts [exceeding 4,500 kilograms (10,000 pounds)]: propane, gasoline, cement, and lubricating and hydraulic oils. The project does not store highly toxic substances in quantities higher than the State of Nevada reporting thresholds (DIRS 148107-Dixon 1999, p. 1).

3.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs each Federal agency "to make achieving environmental justice a part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations."

DOE has identified the minority and low-income communities in the Yucca Mountain region of influence, which consists of Clark, Lincoln, and Nye Counties in southern Nevada. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (DIRS 105004-CRWMS M&O 1999, all) is the basis for information in this section.

> **ENVIRONMENTAL JUSTICE TERMS**
>
> **Minority:** Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other non-white person.
>
> **Low income:** Below the poverty level as defined by the Bureau of the Census.

To identify minority and low-income communities in the region of influence, DOE analyzed Bureau of the Census population designations called *block groups*. DOE pinpointed block groups where the percentage of minority or low-income residents is meaningfully greater than average. For environmental justice purposes, the pinpointed block groups are minority or low-income communities. This EIS considers whether activities at Yucca Mountain could cause disproportionately high and adverse human health or environmental effects to those communities.

3.1.13.1 State of Nevada

Minority persons comprised 21 percent of the population in Nevada in the 1990 census (DIRS 103118-Bureau of the Census 1992, Table P8; DIRS 103119-Bureau of the Census 1992, Table P12). In the 2000 Census, minority persons comprised 35 percent of the population of Nevada (DIRS 156909-Bureau of the Census 2001, p. 1 of Table DP-1; Nevada). It should be noted, however, that between the 1990 Census and the 2000 Census, changes in the Bureau of the Census definitions modified previous race and ethnic categories and for the first time permitted citizens to identify themselves as belonging to more than one category. The Bureau's *Overview of Race and Hispanic Origin*, a Census 2000 Brief issued in March 2001, stated (DIRS 157135-Bureau of the Census 2001, all):

> *Because of these changes, the Census 2000 data on race are not directly comparable with data from the 1990 census or earlier censuses. Caution must be used when interpreting changes in racial composition of the U.S. population over time.*

The environmental justice analysis considered the potential for disproportionately high and adverse impacts on two portions of the overall population—minority communities and low-income communities. While 2000 Census data concerning minority communities in Nevada was available at the block level in time for the Final EIS analysis, comparable 2000 Census data on low-income communities was not. The Final EIS presents 2000 Census data at the block level on minority communities and 1990 Census data at the block group level on low-income communities. This data is the most up-to-date information available for each.

As a consistent criterion for identifying minority and low-income blocks and block groups, DOE employed a 10-percent threshold, meaning that the environmental analysis focused on blocks and block groups in Nevada having a 10-percent or greater minority population or low-income population than the State averages. DOE adopted the 10-percent threshold for the Draft EIS from a 1995 Nuclear Regulatory Commission document, *Interim NRR Procedure for Environmental Justice Reviews* (DIRS 103426-NRC 1995, all). This threshold is consistent with the recent revision of the Nuclear Regulatory Commission's guidance on environmental justice (DIRS 157276-NRC 1999, all).

The environmental justice analysis identified minority communities at the Bureau of the Census block level and low-income communities at the Bureau of the Census block group level. Figure 3-27 shows blocks in the State of Nevada in which 45 percent or more of the population consists of minority persons, according to the 2000 Census. The difference between block level and block group level can be seen in comparing Figure 3-27 to Figure 3-28, which identifies low-income communities at the block group level. The block is a finer resolution; the block group presents the criterion over an aggregate of blocks. Both types of data sets have advantages over the other, depending on the specific analysis being performed. Census blocks can be quite large in rural areas where population density is low because they are associated with a relatively small number of persons. In populous areas such as Las Vegas, the block size is usually quite small and is not clearly depicted on a scale such as that shown in Figure 3-27. Figure 3-29 shows blocks in the Las Vegas area with 45 percent or higher minority population.

The 1990 census characterized about 10 percent of the people in Nevada as living in poverty (DIRS 103120-Bureau of the Census 1992, Table P117). The Bureau of the Census characterizes persons in poverty as those whose income is less than a statistical poverty threshold, which is based on family size and the ages of its members. In the 1990 census the threshold for a family of four was a 1989 income of $12,674 (DIRS 102119-Bureau of the Census 1995, Section 14). In this environmental impact statement, low-income communities are those block groups in which the percentage of persons in poverty equals or exceeds 20 percent as reported by the Bureau of the Census. Figure 3-28 shows low-income communities in Nevada by block group. Figure 3-30 shows low-income communities in the Las Vegas area by block group.

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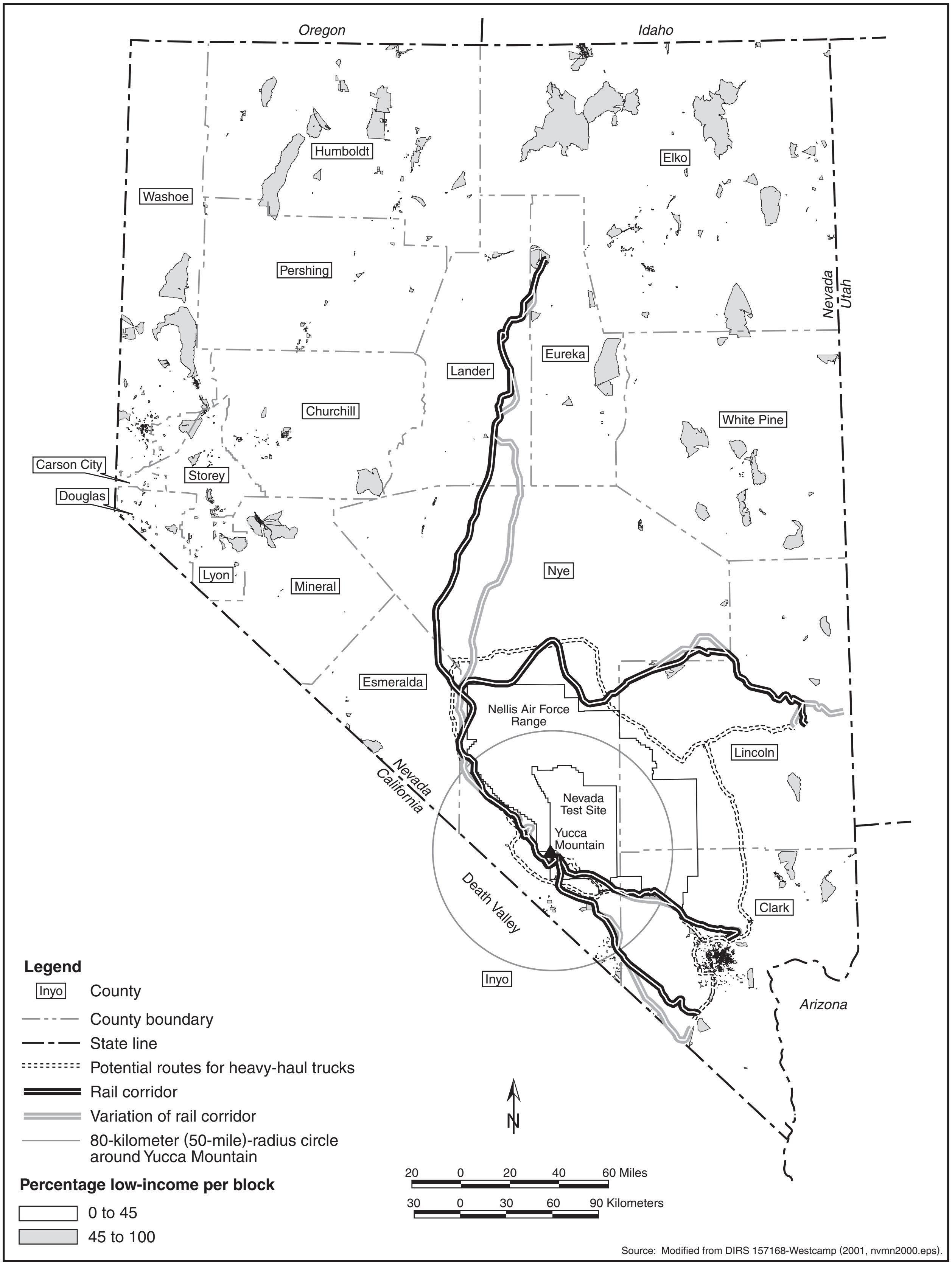

Figure 3-27. Minority communities in Nevada.

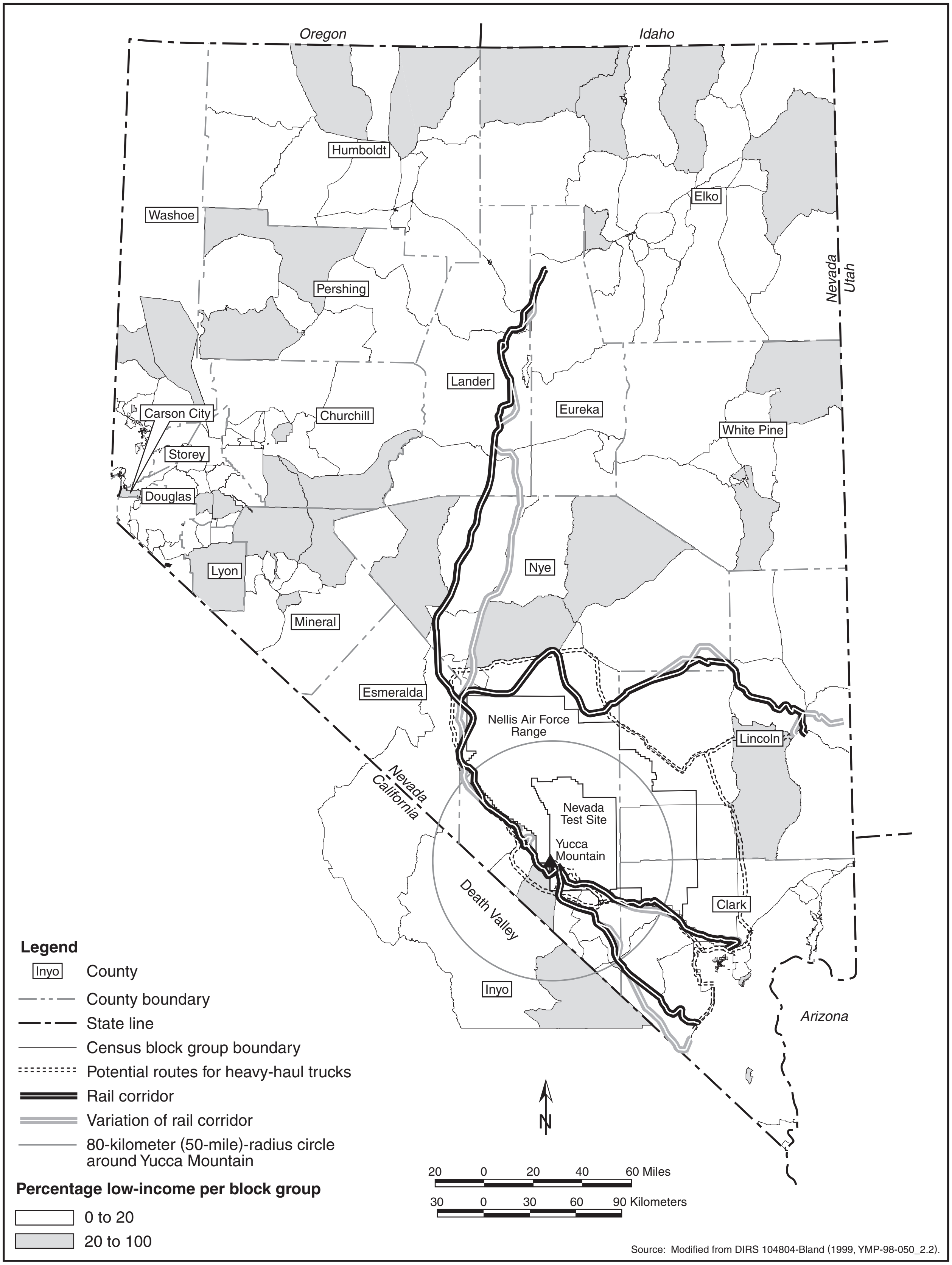

Figure 3-28. Low-income communities in Nevada.

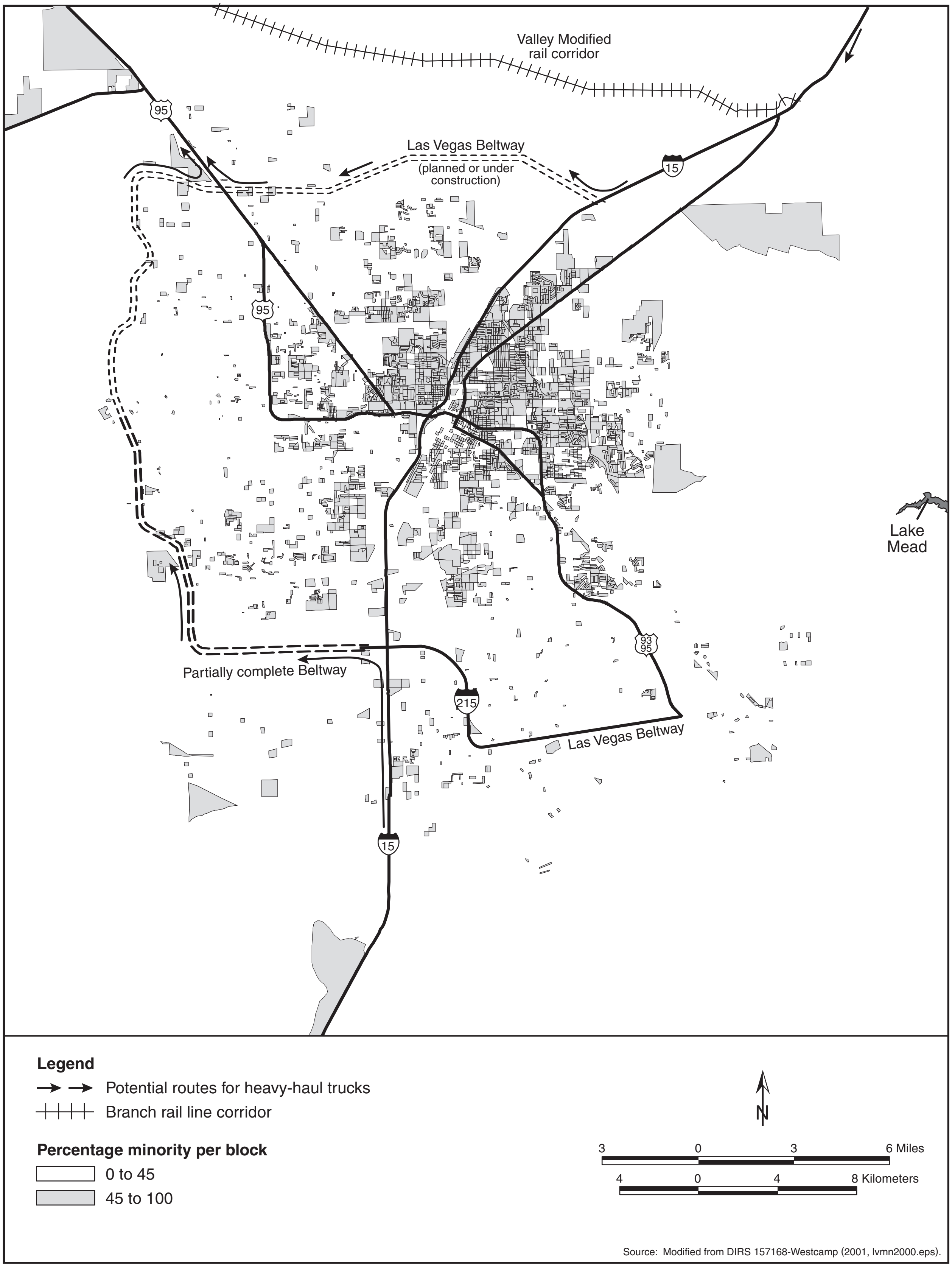

Figure 3-29. Minority census blocks in the Las Vegas metropolitan area.

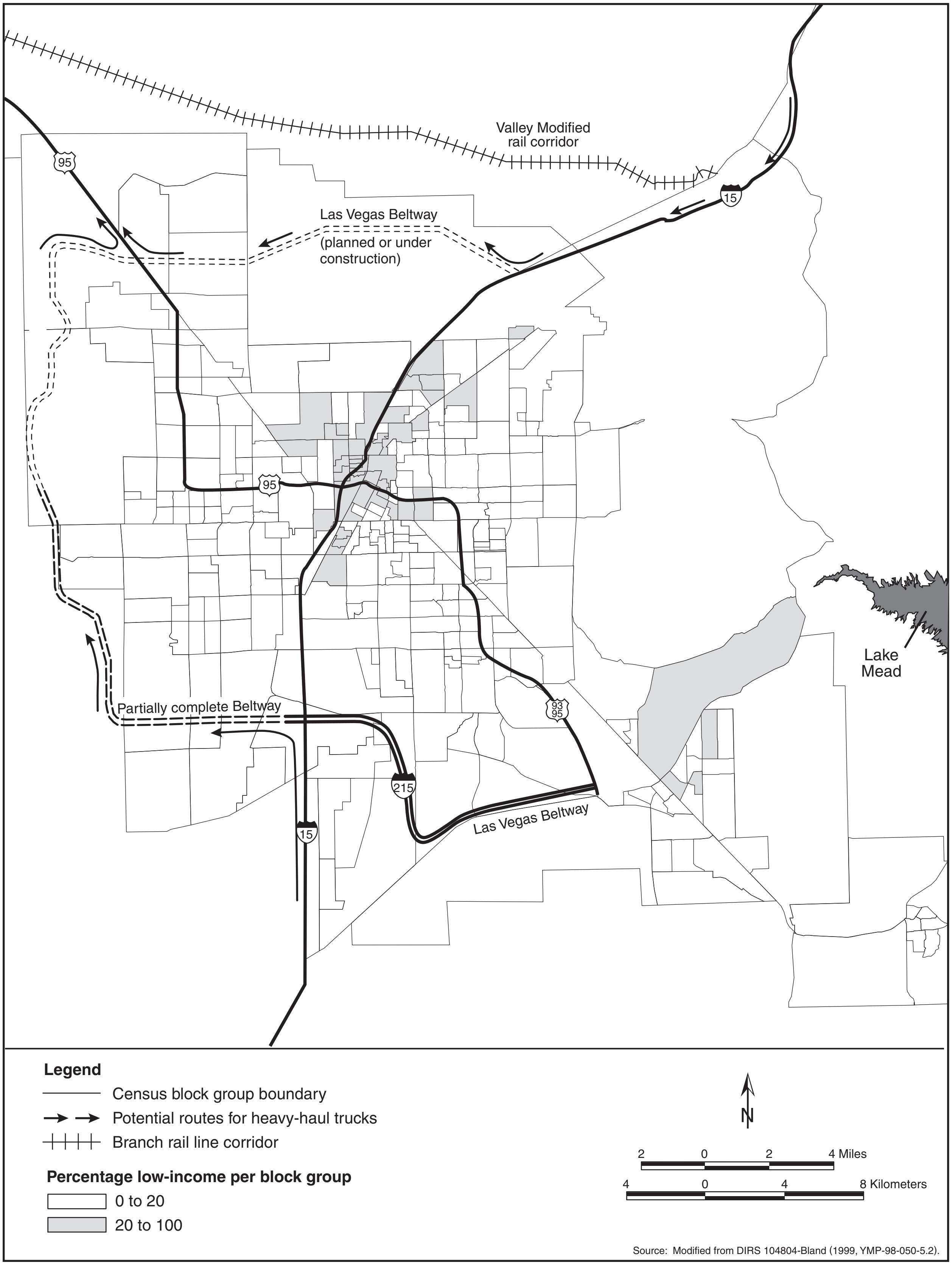

Figure 3-30. Low-income census block groups in the Las Vegas metropolitan area.

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3.1.13.2 Clark County

In 2000, the minority population of Clark County was about 548,000 persons, or 40 percent of the *total population* (DIRS 156909-Bureau of the Census 2001, p. 3 of Table DP-1; Clark County). In 1990, a total of about 80,000 residents, or 11 percent of the Clark County population, was characterized as living in poverty (DIRS 103123-Bureau of the Census 1992, Table P117).

3.1.13.3 Lincoln County

In 2000, the Lincoln County minority population consisted of about 450 persons, or 10 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 10 of Table DP-1; Lincoln County). In 1990, 500 persons, or 14 percent of the population, were characterized as living in poverty (DIRS 103127-Bureau of the Census 1992, Table P117).

3.1.13.4 Nye County

In 2000, the Nye County minority population was about 5,000 persons, or 15 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 13 of Table DP-1; Nye County). In 1990, there were 2,000 persons, or 11 percent of the population, characterized as living in poverty (DIRS 103131-Bureau of the Census 1992, Table P117).

3.1.13.5 Inyo County, California

One block group with a low-income population located in the area of the Stewart Valley in Inyo County, California, lies partly within the 80-kilometer (50-mile) air quality region of influence for the repository (Figure 3-25). DOE performed additional review, including a ground survey, and concluded that low-income persons living in the block group would be likely to live outside the 80-kilometer region of influence for the repository.

3.2 Affected Environment Related to Transportation

This section describes the existing (or baseline) environmental conditions along the candidate rail corridors and truck (legal-weight and heavy-haul) routes to the Yucca Mountain site. The EIS treats these corridors and routes as current analytical tools and refers to them in the present tense. The EIS refers to impacts associated with these alternatives in the conditional voice (would) because they would not occur unless DOE proceeded with the Proposed Action. This convention is applied whenever the EIS discusses the transportation implementing alternatives.

DOE has made revisions to this section since the publication of the Draft EIS to present newly acquired information that contributes to an improved (or updated) understanding of the potentially affected environment, to address more specifically the affected environment along the rail corridor variations in Nevada, and to include information and suggestions for improvement provided through public comment on the Draft EIS and the Supplement to the Draft EIS. The more significant changes occur in the Nevada Transportation section (Section 3.2.2) and particularly in the discussion of candidate rail corridors (Section 3.2.2.1). Key changes to the Final EIS that deal with affected environment for transportation are summarized in the following:

- Incorporated updates to the land use discussions based on actions since the Draft EIS, including land transfers to the Timbisha Shoshone Tribe for establishment of new reservation; and to Clark County for the development of the Ivanpah Valley Airport and the Apex Industrial Park.

- Improved descriptions of land use and aesthetics as a result of the collection of additional information, including perspectives gained from a ground survey of the potential rail corridors.
- Expanded hydrology discussions, primarily by reference to Appendix L, to include results of an effort to compile information on 100-year flood zones along the rail corridors and their variations.
- Augmented the biological resources discussion for potential Nevada rail corridors to biological resources and soils by adding a new soils section to describe several pertinent soil characteristics and their presence along the rail corridors and their variations.
- Expanded cultural resources discussions to incorporate results of an effort to collect and evaluate additional baseline data for the Nevada Transportation for the rail corridors and the heavy-haul truck routes.
- Updated baseline socioeconomic data to incorporate information from the 2000 Census and, as appropriate, information from the State Demographer and local government agencies.
- Expanded the noise discussion to address background levels of ground vibration along both the rail corridors and the heavy-haul truck routes.
- Updated and refined the environmental justice methodology described for candidate rail corridors, including the incorporation of more detailed maps (in Appendix J) of minority populations.
- Expanded information presented in the land use, hydrology (surface-water and groundwater), biological resources, and cultural resources discussions to address more specifically applicable variations to each of the rail corridors.

3.2.1 NATIONAL TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would occur at 72 commercial and 5 DOE sites in 37 states. Transport of these materials to the Yucca Mountain site could involve trains, legal-weight trucks, heavy-haul trucks, and barges; the trains and trucks would travel on the Nation's railroads and highways. This includes existing railroads and highways in Nevada up to a point of departure to specific Nevada routes described in Section 3.2.2. Barges and heavy-haul trucks would be used for short-distance transport of spent nuclear fuel from storage sites to nearby railheads. (Heavy-haul trucks could also be used for Nevada transportation, as discussed in Section 3.2.2.2.)

The national transportation of spent nuclear fuel and high-level radioactive waste (including transportation in Nevada to a point of departure to a specific Nevada transportation route) would use existing highways and railroads and would represent a small fraction of the existing national highway and railroad traffic [less than 1 percent (0.006 percent) of truck miles per year or 0.007 percent of railcar miles per year (DIRS 150989-BTS 1998, p. 6)]. Because no new land acquisition and construction would be required to accommodate these shipments, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes.

The region of influence for public health and safety along existing transportation routes is 800 meters (0.5 mile) from the centerline of the transportation rights-of-way and from the boundary of railyards for incident-free (nonaccident) conditions. The region of influence extends to 80 kilometers (50 miles) to address potential human health and safety impacts from accident scenarios.

DOE used HIGHWAY (DIRS 104780-Johnson et al. 1993, all) and INTERLINE (DIRS 104781-Johnson et al. 1993, all) computer models to derive representative highway and rail routes, respectively, for shipping spent nuclear fuel and high-level radioactive waste. In addition to identifying routes that were used in the analysis, these models were used to estimate population densities along routes in states other than Nevada based on the 1990 Census. The HIGHWAY model identified highway routes between the commercial and DOE generator sites and the proposed repository that would meet the requirements of U.S. Department of Transportation regulations; there are no corresponding Federal regulations that constrain the routing of rail shipments. The analysis used population densities along the highway and rail routes to estimate human health impacts and consequences of transportation. Except in Nevada, the analysis accounted for growth in populations along routes by increasing impacts based on Bureau of the Census forecasts of state populations in 2025, population reported by the 2000 Census for each state, and extrapolation of population growth along routes to 2035. For routes in Nevada, DOE used a Geographic Information System and 1990 census data to develop an initial estimate of the populations within 800 meters (0.5 mile) along highways, commercial rail lines, and the potential corridors for a proposed branch rail line. The analysis of health and safety impacts accounted for growth in populations along Nevada routes by increasing impacts based on forecasts of population growth in Nevada counties using the REMI computer program. The analysis using the REMI program used population growth forecasts provided by Clark County, Nye County, and the State of Demographer and census data for each county provided by the 2000 Census to estimate populations in Nevada in 2035.

3.2.1.1 Highway Transportation

USE OF REPRESENTATIVE ROUTES IN IMPACT ANALYSIS

At this time, prior to approval of the site for development and operation of a repository and years prior to a possible first shipment, the actual routes that would be used to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain have not been identified. However, the highway and rail routes used for analysis in this EIS are representative of routes that could be used. The highway routes conform to U.S. Department of Transportation regulations (49 CFR 397.101). These regulations, developed for transportation of Highway Route Controlled Quantities of Radioactive Materials, require such shipments to use preferred routes that would reduce the time in transit. A preferred route is an Interstate System highway, bypass, or beltway, or an alternative route designated by a state routing agency. Alternative routes could be designated by states and tribes under U.S. Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with local jurisdictions and other states. Federal regulations do not restrict the routing of rail shipments. However, for the analysis, as discussed in Appendix J, Section J.1.1.3 of the EIS, DOE assumed routes for rail shipments that would provide expeditious travel, use of high quality track, and the minimum number of interchanges between railroads.

Highway (legal-weight truck) transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use local highways near the commercial and DOE sites and near Yucca Mountain, Interstate Highways, Interstate bypasses around metropolitan areas, and preferred routes designated by state routing agencies where applicable. DOE used the HIGHWAY computer program (DIRS 104780-Johnson et al. 1993, all) to derive representative highway routes for shipping spent nuclear fuel and high-level radioactive waste between the commercial and DOE sites and the proposed repository. Population density distributions, with the exception of those routes in Nevada, were calculated along the routes to support human health risk consequences. DOE used a Geographic Information System to calculate the population density distributions for routes in Nevada.

Appendix J describes the representative routes used for analysis in this EIS. Actual transportation mode and routing decisions would be made on a route-specific basis during the transportation planning process, if a decision was made to build a repository at Yucca Mountain.

3.2.1.2 Rail Transportation

In most cases, rail transportation of spent nuclear fuel and high-level radioactive waste would originate on track operated by shortline rail carriers that provide service to the commercial and DOE sites. At railyards near the sites, shipments in general freight service would switch from trains and tracks operated by the shortline rail carriers to trains and tracks operated by national mainline railroads. Figure 2-23 in Chapter 2 shows existing mainline track for the major U.S. railroads that DOE could use for shipments to Nevada. This interlocking network has about 290,000 kilometers (180,000 miles) of track that link the major population centers and industrial, agricultural, and energy and mineral resources of the Nation (DIRS 103069-AAR 1996, all). With the exception of shortline regional railroads that serve the commercial and DOE sites, DOE anticipates that cross-country shipments would move on mainline railroads.

Rail transportation routing of spent nuclear fuel and high-level radioactive waste shipments is not regulated by the U.S. Department of Transportation. The routes used in this EIS were derived from the INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all). The identification for purposes of analysis of these routes was based on current railroad practices using existing routes. Appendix J describes the rail routes used in this EIS analysis.

3.2.1.3 Barge and Heavy-Haul Truck Transportation

Commercial sites that do not have direct rail service could ship spent nuclear fuel on heavy-haul trucks or barges to nearby railheads. Heavy-haul trucks would use local highways to carry the spent nuclear fuel to a nearby railhead for transfer to railcars for transport to Nevada. Barge shipments would use navigable waterways accessible from the nuclear plant site. These shipments would travel on the waterways to nearby railheads for transfer to railcars for transport to Nevada. Appendix J describes the heavy-haul truck and barge routes used in this EIS analysis.

3.2.2 NEVADA TRANSPORTATION

Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would be transported to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. The discussion of national transportation modes and routes in Section 3.2.1 addresses the affected environment for legal-weight truck transport from commercial and DOE facilities to the Yucca Mountain site, including travel in Nevada. This section addresses the affected environment in Nevada for candidate rail corridors, heavy-haul truck routes, and potential locations for an intermodal transfer station that DOE could use for transporting spent nuclear fuel and high-level radioactive waste and that would require new construction.

Legal-weight truck shipments in Nevada would use existing highways and would be a very small fraction of the total traffic [less than 0.5 percent of commercial vehicle traffic on U.S. Highway 95 in southern Nevada (DIRS 103405-NDOT 1997, p. 9; DIRS 104727-Cerocke 1998, p. 1). Because no new land acquisition and construction would be required to accommodate legal-weight trucks, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes from legal-weight truck shipments. Appendix J contains baseline environmental information related to human health and safety and the impacts from accident scenarios.

To allow large-capacity rail cask shipments to the repository, DOE is considering the construction of a new branch rail line or the establishment of heavy-haul truck shipment capability. Sections 3.2.2.1 and 3.2.2.2 describe the existing (or baseline) environment for each of the candidate rail corridors and heavy-haul truck routes and for potential locations for an intermodal transfer station. The locations selected for candidate rail corridor starting points and for a potential intermodal transfer station are all accessible by main rail lines that are currently in operation. National rail transportation would simply involve routings to accommodate the selected starting point for Nevada transportation. DOE would prefer to use a branch rail line to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

3.2.2.1 Environmental Baseline for Potential Nevada Rail Corridors

This section discusses the environmental characteristics of land areas that could be affected by the construction and operation of a rail line to transport spent nuclear fuel and high-level radioactive waste to the proposed repository. It describes the environmental conditions in five alternative rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. Chapter 2, Section 2.1.3.2, describes these corridors in more detail. Figures 6-15 through 6-19 in Chapter 6 show detailed maps for these corridors.

To define the existing (or baseline) environment along the five proposed rail corridors; DOE has compiled environmental information for each of the following subject areas:

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.1.1)
- *Air quality and climate:* The quality of the air and the climate (Section 3.2.2.1.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.1.3)
- *Biological resources:* Important biological resources (Section 3.2.2.1.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.1.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.1.6)
- *Noise and vibration:* The existing noise environments (Section 3.2.2.1.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.1.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.1.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.1.10)

A Geographic Information System provided population distributions for differing population zones (urban, rural, suburban) along the candidate rail corridors. This approach, as discussed in Section 3.2.1, differs from the analysis for national transportation, which used the INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all) (see Chapter 6 for more detail).

DOE expects waste quantities generated by rail line construction and operation to be minor in comparison to those from repository construction and operation. As such, no discussion of existing waste disposal infrastructure along the routes is provided.

DOE evaluated the potential impacts of the implementing alternatives in regions of influence for each of the subject areas listed above. Table 3-35 defines these regions, which are specific to the subject areas, in which DOE could reasonably expect to predict potentially large impacts related to rail line construction and operation. The following sections describe the various environmental baselines for the rail implementing alternatives.

TERMS RELATED TO IMPLEMENTING ALTERNATIVE RAIL LINES

DOE has expanded the discussion of the affected environment in the corridors considered for rail use in this EIS. This includes the use of several terms that have specific meanings in the context of the discussion. In addition to this discussion, DOE has used these terms in the transportation analyses described in Chapter 6 and Appendix J. The following list defines these terms:

Implementing alternative – An action or proposition by DOE necessary to implement the Proposed Action and to enable the estimation of the range of reasonably foreseeable impacts of that action. In other words, an implementing alternative represents a feasible option that DOE could implement based in part on this EIS (for example, the selection of a branch rail line corridor).

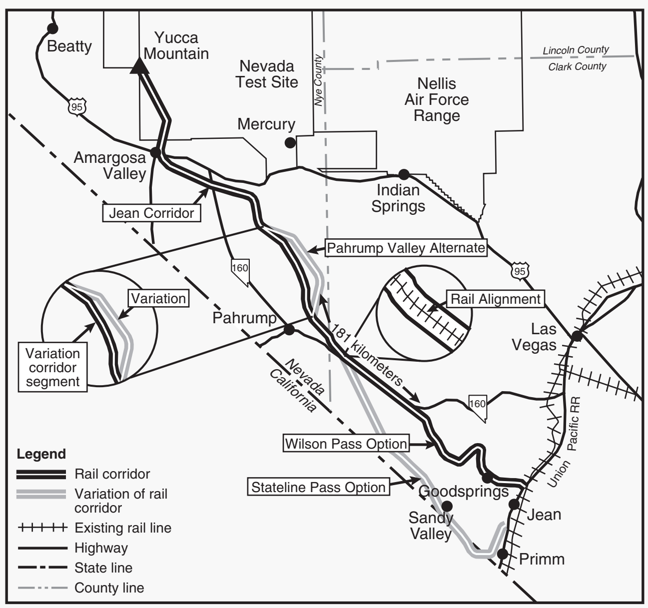
The implementing rail alternatives for Nevada transportation are the five corridors—Carlin, Caliente, Caliente-Chalk Mountain, Jean, and Valley Modified—for a new branch rail line:

Corridor – A strip of land in Nevada, approximately 400 meters (0.25 mile) wide, that encompasses one of several possible routes through which DOE could build a rail line to transport spent nuclear fuel, high-level radioactive waste, and other material to and from the Yucca Mountain Repository site.

Alignment – The location of a rail line in a corridor. DOE has not determined the final alignment for a branch rail line in any of the candidate rail corridors.

Variation – In this context, a strip of land, approximately 400 meters (0.25 mile) wide, from one point along a corridor to another point on the same corridor that describes a different route. There are three types of variation:

> ***Option –*** In this context, a variation based on a determination that the location of a corridor segment is essentially equivalent to that of another option, considering environmental and engineering factors.
>
> ***Alternate –*** In this context, a variation in the location of a corridor segment to mitigate a potential adverse environmental or engineering factor.
>
> ***Connection/Connector –*** In this context, a short variation of a corridor that connects a corridor to a commercial railroad or that connects an alternate or option of a corridor to the corridor.



DOE believes that this EIS provides the environmental impact information necessary to select a rail corridor. However, before DOE could select an alignment in that corridor, it would have to conduct additional field surveys; State, local, and tribal government consultations; engineering and environmental analyses; and National Environmental Policy Act reviews.

Table 3-35. Regions of influence for rail implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or whose ownership or use would change as a result of construction and use of branch rail line
Air quality and climate	The atmosphere in the vicinity of sources of criteria pollutants that would be emitted during branch rail line construction and operations, and particularly the Las Vegas Valley for implementing alternatives where constructing and operating a branch rail line could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards.
Hydrology	*Surface water:* areas near where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that could be affected by eroded soil or potential spills of construction contaminants *Groundwater:* aquifers that would underlie areas of construction and operations and aquifers that might be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands and riparian areas inside the 400-meter-wide[a] corridors; habitat, including jurisdictional wetlands outside the corridor that could be disturbed by rail line construction and operations; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flows; migratory ranges of big game animals that could be affected by the presence of a branch rail line
Cultural resources	Lands inside the 400-meter-wide rail corridors
Socioeconomic environments	Clark, Lincoln, Nye and other counties that a potential branch rail line would traverse
Public health and safety	800 meters[b] on each side of the rail line for incident-free transportation, 80-kilometer[c] radius for potential impacts from accident scenarios
Noise and vibration	Inhabited commercial and residential areas where noise and vibration from rail line construction and operations could be a concern
Aesthetics	The landscapes along the potential rail corridors with aesthetic qualities that could be affected by construction and operations
Utilities, energy, and materials	Local, regional, and national supply infrastructure that would be required to support rail line construction and operations
Environmental justice	Locations of minority, low-income, and Native American populations along the rail implementing alternatives; includes the regions of influence for each of the preceding individual subject or impact areas

a. 400 meters = 0.25 mile.
b. 800 meters = 0.5 mile.
c. To convert kilometers to miles, multiply by 0.62137.

3.2.2.1.1 *Land Use and Ownership*

Table 3-36 summarizes the estimated land commitment and current ownership or control of the land in each rail corridor. It addresses both the representative corridor and the range of values applicable to corridor variations. Public lands in and near the corridors are used for a variety of activities including grazing, mining, and recreation. All public land in the Caliente, Carlin, Jean, and Valley Modified Corridors is open to mining and mineral leasing laws and offroad vehicle use, with restrictions in some areas (DIRS 101504-BLM 1979, all; DIRS 101523-BLM 1994, all; DIRS 103080-BLM 1999, all). The rail corridor descriptions, unless otherwise noted, are from DIRS 104993-CRWMS M&O (1999, all), DIRS 101214-CRWMS M&O (1996, all) and DIRS 104560-YMP (1998, all).

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Table 3-36. Land ownership for the candidate rail corridors.[a]

Corridor	Land in corridor: Totals (km^2)[b,c]	Ownership or control (percent)[d]: BLM	USAF	DOE	Private	Tribal	Other
Representative corridors							
Caliente	205	188 (92)	11 (5)	4.6 (2)	0.9 (<1)	0	0
Carlin	208	179 (86)	11 (5)	4.6 (2)	14 (7)	0	0
Caliente-Chalk Mountain	138	78 (57)	22 (16)	38 (27)	0.8 (<1)	0	0
Jean	72	60 (83)	0	8.5 (12)	3.5 (5)	0	0
Valley Modified	63	34 (53)	7 (11)	21 (32)	0.2 (<1)	0	1.8 (3)
Ranges for corridors with variations (all in km^2)							
Caliente	205 - 221	188 - 216	0 - 11	4.6	0.9 - 2.5	0 - 1.6	0
Carlin	205 - 218	177 - 201	0 - 11	4.6	7.3 - 1.5	0 - 1.6	0
Caliente-Chalk Mountain	138 - 153	77 - 89	22	32 - 38	0.8 - 1.1	0	0
Jean	72 - 82	60 - 69	0	8.5	0.1 - 3.5	0	0
Valley Modified	63 - 65	30 - 37	3.6 - 7.5	21	0 - 0.2	0	1.7 - 4.1

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert square kilometers (km^2) to acres, multiply by 247.1.
c. Totals might differ from sums due to rounding.
d. Bureau of Land Management (BLM) property is public land administered by the Bureau; U.S. Air Force property is the Nellis Air Force Range; DOE property is the Nevada Test Site; tribal land is the Timbisha Shoshone Trust Lands; and the Other designation is the Desert National Wildlife Range managed by the Fish and Wildlife Service.

Caliente. Most of the lands associated with the Caliente Corridor (92 percent) are public lands managed by the Ely, Battle Mountain, and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (DIRS 101523-BLM 1994, all), the *Department of the Interior Final Environmental Impact Statement, Proposed Domestic Livestock Grazing Management Program for the Caliente Area* (DIRS 101504-BLM 1979, all), the *Final Legislative Environmental Impact Statement, Timbisha Homeland* (DIRS 154121-DOI 2000, all) the *Caliente Management Framework Plan Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat* (DIRS 103080-BLM 1999, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

The U.S. Air Force uses about 5 percent of the lands associated with the Caliente Corridor. The corridor crosses the western boundary of the Nellis Air Force Range near Goldfield and again northeast of Scottys Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all).

DOE uses about 2 percent of the lands associated with the Caliente Corridor. The corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all).

Less than 1 percent of the land associated with the Caliente Corridor is private. The corridor crosses private land near Caliente.

The Caliente Corridor (Chapter 2, Figure 2-26) begins in Lincoln County, at an existing section of the Union Pacific Railroad at Eccles, and moves north across mostly Bureau of Land Management lands toward U.S. 93 near Comet Siding, which is south of Panaca. Two alternate sections are being evaluated as the beginning point of this corridor. One is west of a section of the Union Pacific Railroad at Crestline [approximately 3.2 kilometers (2 miles) west of the Dixie National Forest]. From that point it continues west across Bureau of Land Management lands to the point south of Panaca where it joins the main corridor. The other alternate section originates at the Town of Caliente. This section travels north along an existing Union Pacific rail line, running parallel to U.S. 93 to the intersection with the main rail corridor in the same area just south of Panaca. Although the 1990 Bureau of Land Management Master Title Plats indicate that the former Union Pacific right-of-way remains active, the right-of-way ownership for the abandoned rail bed is not clear. Each of these starting sections passes through Meadow Valley Wash. Approximately 3.2 kilometers (2 miles) north of this corridor (just north of Panaca) is the Cathedral Gorge State Park.

The section from Caliente has seen more development and has more inhabitants than the Crestline and the Eccles corridor initiation locations. A utility transmission line extends from Caliente to an area west of Panaca. The Eccles, Caliente, and Crestline Options cross private lands. There are numerous houses, farms, and ranches north of Caliente and extending toward Panaca. Areas of ponded water and streams associated with the Meadow Valley Wash occur through this area along the eastern side of U.S. 93 (which in this area is part of the State Scenic Byway). The Crestline and Caliente Options cross two rights-of-way: one for U.S. 93 and one telephone; the Eccles Option does not cross any rights-of-way. Past the area where the alternate starting sections converge, the corridor passes west on Bureau of Land Management lands near Bennett Springs Road, moves through the Highland Range in the area of Bennett Pass, and continues across Bureau land in the northern section of the North Pahroc Range. Through this section the corridor passes through two pipeline, one telephone, and two road rights-of-way, and east of a wilderness study area. The corridor then moves through Bureau lands west of Nevada State Route 318, along the Lincoln/Nye County line north of the Seaman Range. The corridor passes just north of the Weepah Springs Wilderness Study Area located in the vicinity of Timber Mountain in Lincoln County.

The rail corridor splits in the area of Timber Mountain Pass, with a possible section (the White River Alternate) going north of the Seaman Range into the White River Valley and then passing back to the south and west along and through the Golden Gate Range. The corridor continues on Bureau of Land Management lands in a general southwesterly direction and back into Lincoln County through Garden and Sand Spring Valleys. In Garden Valley, the corridor and the Garden Valley Alternate wind around private land. The corridor crosses one road and one pipeline right-of-way, and five oil or gas leases. The Garden Valley Alternate crosses two road and two pipeline rights-of-way. The corridor continues on Bureau land and passes generally to the southwest into Nye County, to land around the Reveille Range north of the Cedar Pipeline Ranch. It then turns north toward Warm Springs, passing between the Reveille and Kawich Ranges, and passing to the east of the Eden Creek Ranch. As the corridor passes between the southern portion of the Kawich and South Reveille Ranges, it passes just east of the Kawich Wilderness Study Area and encroaches on the South Reveille Wilderness Study Areas. The corridor turns southwest again toward the Nellis Air Force Range, passing the Town of Golden Arrow and the Reeds Ranch, which is just north of the Nellis Range. Also north of the Nellis Range, the Kawich Range contains several ranches and small towns and communities, as well as abandoned and current mining operations.

The Toiyabe National Forest is approximately 6.4 kilometers (4 miles) northwest of the corridor as it passes north of the Kawich Range. Numerous two-track roads surround the Kawich Range providing access to grazing allotments, mining claims, and recreational areas. The corridor then passes along the northern boundary of the Nellis Air Force Range through Ralston Valley. From the merging of the Garden Valley Alternate to the western boundary of the Nellis Range, the corridor crosses or travels along two Bureau of Land Management utility corridors. The corridor also crosses two road, two pipeline, and two powerline rights-of-way. It then turns south along the western boundary of the Nellis Range. Both gravel and two-track roads are present in that area, and throughout the remainder of the corridor, with many entering the Nellis Range.

The corridor splits east of the Town of Goldfield, with the alternate segment going west of Blackcap Mountain, through Bureau of Land Management land and two parcels of private property to the south along the Nye/Esmeralda County line. The corridor traverses a section on the Nellis Air Force Range. The corridor and the alternate segment rejoin in Bureau land along the Nye/Esmeralda County line near the Town of Ralston.

The corridor proceeds south until it splits again around the Town of Scottys Junction in Nye County. One segment, the Bonnie Claire Alternate, passes to the west, crossing U.S. 95 and State Route 267. This western segment passes through 11 square kilometers (2,800 acres) of formerly Bureau of Land Management lands transferred to the Timbisha Shoshone. This parcel of land is being proposed for Tribal economic development (tourism) and Tribal housing (DIRS 154121-DOI 2000, all). In addition to rights-of-way for U.S. 95 and State Route 267, the Bonnie Claire Alternate crosses two powerline and one telephone rights-of-way. It passes through a portion of private land south of U.S. 95. The corridor crosses into the Nellis Air Force Range for a short distance northeast of Scottys Junction before moving back into Bureau of Land Management land. The alternate segment merges with the corridor, which then follows U.S. 95 toward the Town of Beatty, which it passes to the east. A minor segment, the Oasis Alternate, goes slightly farther east of Beatty before merging with the corridor. A little farther to the southeast, the Beatty Wash Alternate then diverges for a short distance until it realigns with the corridor and crosses a Bureau of Land Management utility corridor several times.

Death Valley National Park, west of Beatty at the point closest to the rail corridor, is approximately 11 kilometers (7 miles) to the west. The area surrounding Beatty and extending southeast toward Amargosa Valley has several small towns and numerous current and historic mining operations. There are also campgrounds along U.S. 95. The corridor bypasses most of these areas by moving between Beatty and the Nellis Air Force Range. It continues generally to the south and enters DOE property west of Yucca Mountain and north of the Town of Amargosa Valley.

Carlin. Most of the lands associated with the Carlin Corridor (about 86 percent) are public lands managed by the Battle Mountain and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Draft Shoshone-Eureka Resource Management Plan and Environmental Impact Statement* (DIRS 103077-BLM 1983, all), the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (DIRS 101523-BLM 1994, all), the *Final Legislative Environmental Impact Statement, Timbisha Homeland* (DIRS 154121-DOI 2000, all) and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

The U.S. Air Force uses about 5 percent of the lands associated with the Carlin Corridor. The combined Carlin/Caliente Corridor crosses into the western portion of the Nellis Air Force Range near Goldfield and again northeast of Scottys Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 2 percent of the lands associated with the Carlin Corridor. The combined Carlin/Caliente Corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

About 7 percent of the land associated with the Carlin Corridor is private. The corridor crosses private roads in the northern part of the route, from Beowawe through Crescent Valley.

The Carlin Corridor (Chapter 2, Figure 2-26) begins near the Town of Beowawe in Eureka County, at an existing Union Pacific Railroad line. The corridor moves south along Crescent Valley through a mix of private and Bureau of Land Management lands that extend south of the Town of Crescent Valley, near the Dean Ranch. The corridor crosses numerous gravel and two-track roads, most of which lead to adjoining valleys, ranches, or grazing allotments in Crescent Valley and in the adjacent mountains. The corridor runs east of State Route 306 and continues south toward the Dean Ranch.

Just north of the Dean Ranch and east of State Route 306, the corridor splits. The corridor itself crosses State Route 306 to the west and continues south and west of the Dean Ranch, and the alternate segment travels south and east of the Dean Ranch. The two rejoin south of the ranch on Bureau of Land Management land near the Cortez Airstrip west of the Cortez Gold Mine. An expansion of the Cortez Gold Mine operations, recently approved by the Bureau of Land Management (DIRS 155095-BLM 2000, all), involves the disturbance of an additional 18 square kilometers (4,450 acres) of public lands. This action includes expansion of an existing open pit, extension of process solution pipelines, modifications to the existing road between Gold Acres and the Cortez milling facility, the increase of waste rock and tailings facilities, and a pipeline right-of-way from the mine to the Dean Ranch for supplying water to the ranch. The corridor passes from Eureka County into Lander County near the Dean Ranch. Through Crescent Valley it crosses private lands and two road, one powerline, and two telephone rights-of-way. One of the road rights-of-way runs from the Gold Acres Mine to the Cortez Mine milling facility. The Crescent Valley Alternate crosses private lands, one right-of-way, and another road with no right-of-way listed. Near the Town of Gold Acres, the Gold Acres Mine and its spoils pile are the dominant features in the valley. There are numerous active and abandoned mine sites in the area of the Shoshone Range and the Cortez Mountains. Also in this area are several small towns and numerous ranches in the Crescent Valley and Grass Valley.

The corridor passes east and south of the Cortez Airstrip and through a northern portion of the Toiyabe Range that is not part of the Toiyabe National Forest. In this section of the Toiyabe Range, there is a split in the corridor for engineering design reasons. The corridor passes into Grass Valley west of Hot Springs Point, extending to the south, east of the Cowboy Rest Ranch. It follows the western side of the valley until it splits north of the Grass Valley Ranch. The corridor segment runs west of the Grass Valley Ranch, where it crosses private lands adjacent to Bureau of Land Management lands. Roads connect Grass Valley to the surrounding areas, most of which appear to be two-track roads that extend from main gravel roads in the valley to the mountainous areas on both sides of the valley. Some of these two-track roads might be for recreation, but are probably used to access Bureau grazing or mining allotments in the area. The corridor follows Bureau lands and continues to the south. The alternate segment (the Steiner Creek Alternate) passes to the east of the Grass Valley Ranch, along the western base of the Simpson Park Mountains. The Steiner Creek Alternate passes close to the Simpson Park Wilderness Study Area in Lander County just east of the Grass Valley Ranch. The corridor and alternate segments rejoin near Bates Mountain and continue south through Bureau lands in Rye Patch Canyon, still following the western edge of the Simpson Park Mountains. In this area, the corridor splits again, still on Bureau lands. The corridor and the Rye Patch Alternate diverge to bypass sensitive habitat at Rye Patch Spring. Both cross two road rights-of-way. At this point, the corridor splits into two major variations, the Big Smoky Valley Option and the Monitor Valley Option, both of which run mostly through Bureau lands. Soon after this split, both cross the Nye/Lander County line.

The Big Smoky Valley portion of the corridor begins just south of the Givens Ranch in Rye Patch Canyon and continues south along the eastern side of the valley. U.S. 50, a State Scenic Byway, crosses the Valley from east to west, just to the south of the Givens Ranch. The Lander/Nye County line is approximately 26 kilometers (16 miles) south of U.S. 50. South of the county line, the Big Smoky Valley Alternate crosses three road, one flume, four powerline, and two pipeline rights-of-way, and a Desert Land Entry withdrawal parcel west of the Town of Hadley. It also passes through a Bureau of Land Management utility corridor. The Big Smoky Valley is comprised of Bureau lands and private property. The Bureau lands consist primarily of grazing allotments. The main road, State Route 376, runs along the western side of the valley. Other roads cross the valley, generally running east-west, leading to the National Forest on both sides of the valley and to small communities and public recreation areas. Some of these are Forest Service roads that cross the National Forest and connect with State or other Forest Service roads in adjacent valleys. One of the most frequently used public recreation areas is Peavine Public Campgrounds in the southern part of the Toiyabe National Forest in the Toiyabe Range. There are numerous ranches, most along the western edge of the valley. Small roads (two-tracks) run along the valley floor, generally through grazing allotments. A power line runs along the route, just west of the Town of Millers, and continues north up the valley near Manhattan. In this area, the valley is flanked by the Toquima and Toiyabe Ranges, both of which are part of the Toiyabe National Forest. The southern portion of Big Smoky Valley narrows, and there are many small towns in this portion of the valley, limiting the opportunity to avoid private land.

The corridor passes west of State Route 376 and proceeds to the west of the Round Mountain Golf Course near the Town of Hadley and its airport. The route follows the western edge of the valley and continues to the south near the San Antonio Ranch, running between the Town of Midway Station and the San Antonio Mountains, where there is a large section of private land, most of which probably is associated with mining. The route crosses Secondary State Route 89 and, after crossing into Esmeralda County, continues south across U.S. 95/6 west of Tonopah. It then turns to the southeast toward Nellis Air Force Range, crossing U.S. 95 again and moving south and east of the Town of Klondike, where it joins with the Monitor Valley Alternate.

The Monitor Valley Option runs east from the Rye Patch Canyon area along the Simpson Park Mountains, near the Hicks Summit Petroglyph Recreation Area. It crosses U.S. 50 and extends south into Monitor Valley, generally following Stoneberger Creek and adjacent to a two-track road along the western side of the valley. It then continues through the valley east of Secondary State Route 82 and moves into Nye County, passing east of the Monitor Ranch between Potts and the Toquima Range to the west. Monitor Valley is bounded on both east and west by the Toiyabe National Forest, which includes several wildlife areas, recreation areas, ranches, and small communities. Numerous roads cross the valley, leading through the adjacent mountain ranges or to isolated ranches and grazing allotments. The option remains to the east of Secondary State Route 82, continuing south to the community of Belmont, where the valley narrows, and follows along or just west of Secondary State Route 82. Past Belmont, the option follows Secondary State Route 82 to its intersection with State Route 376 and then continues south through Ralston Valley, crossing U.S. 6 west of the Tonopah Municipal Airport. There is a state prison on the western side of State Route 376, approximately 13 kilometers (8 miles) north of U.S. 6. The option continues south until it rejoins the corridor near the Nye/Esmeralda County line. In Monitor Valley, the option crosses one telephone, two road, and one pipeline rights-of-way. There are two Desert Land Entry parcels between the Town of Hadley and the Nye/Esmeralda County line.

The rejoined corridor and option intersect the Caliente Corridor (as described above) near Mud Lake in the northwest corner of the Nellis Air Force Range before continuing to Yucca Mountain. As with the Caliente Corridor, the Carlin Corridor's Bonnie Claire Alternate passes through an area recently designated for the creation of a section of the Timbisha Shoshone Reservation on lands transferred from the Bureau of Land Management (DIRS 154121-DOI 2000, all).

Caliente-Chalk Mountain. Most of the lands associated with the Caliente-Chalk Mountain Corridor (about 57 percent) are public lands managed by the Ely Office of the Bureau of Land Management. Detailed information on land use is available in DIRS 101504-BLM (1979, all) and DIRS 103080-BLM (1999, all).

The U.S. Air Force uses about 16 percent of the lands associated with the Caliente-Chalk Mountain Corridor. The corridor enters the Nellis Air Force Range west of Rachel, Nevada, and travels south through the range. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 27 percent of the lands associated with the Caliente-Chalk Mountain Corridor. The corridor crosses the northern border of the Nevada Test Site and travels to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

Less than 1 percent of the lands associated with the Caliente-Chalk Mountain Corridor is private. The combined Caliente and Caliente-Chalk Mountain Corridor crosses private lands near Caliente.

The beginning portion of the Caliente-Chalk Mountain Corridor (Chapter 2, Figure 2-26) is the same as the beginning portion of the Caliente Corridor described above. The two corridors and their variations are identical until they reach the area of Sand Spring Valley.

At Sand Spring Valley, the Caliente-Chalk Mountain Corridor splits from the Caliente Corridor and continues on Bureau of Land Management land to pass generally south along the Lincoln/Nye County line. The corridor crosses State Route 375 and enters the Nellis Air Force Range east of Queen City Summit.

The Caliente-Chalk Mountain Corridor continues south just west of Chalk Mountain and into the northern portion of Emigrant Valley. It passes numerous paved and two-track roads through this area. The corridor passes almost due south into the Nevada Test Site. Once inside the Test Site the corridor divides just north of the main infrastructure area. The Orange Blossom Road Option continues generally to the south just east of the infrastructure area in the eastern portion of the Test Site. This option continues southeast of French Peak and then passes generally to the west around infrastructure and just north of Skull Mountain. It continues generally westward, passing infrastructure south of the Calico Hills, crossing Fortymile Wash, and into the proposed repository area. It crosses a power right-of-way twice and a waterline right-of-way. It also crosses Nevada Test Site roads.

The Mercury Highway Option splits from the corridor just north of the large Nevada Test Site infrastructure area. This option turns generally south along the east of the Elena Range through Yucca Flat and the center of the Test Site, crossing roads and bypassing existing infrastructure until it joins with the Orange Blossom Road Option just north of Skull Mountain and continues to the proposed repository site.

The Area 4 Alternate splits from the Mercury Highway Option along the western edge of the Nevada Test Site infrastructure area in the vicinity of Syncline Ridge where it joins with the Tonopah Option. This option crosses the Mercury Highway.

The Mine Mountain Alternate splits from the Area 4 Alternate in the vicinity of Mine Mountain Junction to minimize impacts to cultural sites in the area. It splits for only a short distance and then rejoins the Area 4 Alternate.

The Tonopah Option travels just inside the northern Nevada Test Site boundary westward until it begins to turn to the south along the eastern edge of the Elena Range bypassing Test Site infrastructure areas. The route passes along the western edge of Barren Wash until it strikes westward south of the Calico Hills and continues across Fortymile Wash.

The Caliente-Chalk Mountain Corridor crosses lands in which paved, gravel, and two-track roads are abundant. These roads provide access to grazing and mining allotments and recreational areas on Bureau of Land Management lands. Some roads provide access to recreational areas on State and Federal lands (Humboldt National Forest).

Jean. Most of the lands associated with the Jean Corridor (about 83 percent) are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in DIRS 103079-BLM (1998, all).

DOE uses about 12 percent of the lands associated with the Jean Corridor. The corridor enters the Nevada Test Site near Amargosa Valley traveling north to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

About 5 percent of the land associated with the Jean Corridor is private. The corridor crosses private lands in the Pahrump Valley.

The Jean Corridor consists of the Wilson Pass Option (the corridor) and the Stateline Pass Option starting sections (Chapter 2, Figure 2-26). The Wilson Pass Option begins along the Union Pacific rail line just north of Jean. The corridor extends northwest and runs north of State Route 161, along Bureau of Land Management lands toward Goodsprings, and along the southern edge of the Bird Spring Range. It crosses two pipeline, three road, and two powerline rights-of-way.

The corridor passes through the Bureau of Land Management mining area containing the Bluejay, Snowstorm, and Pilgrim Mines, and runs within about 2 kilometers (1.2 miles) south of the Toiyabe National Forest in the Spring Mountains. The area contains a number of access roads to the mine sights. Several State and access roads associated with the National Forest cross the corridor. The corridor passes just to the south of the National Forest and traverses Wilson Pass along Bureau lands, continuing to the northwest until its intersection with State Route 160. It then continues across a Bureau utility corridor and continues on Bureau lands north of State Route 160 until it intersects the Stateline Pass Option.

The Stateline Pass Option begins in Ivanpah Valley along the Union Pacific rail line south of Jean and just north of Roach Lake, in an area that Clark County is proposing as the location for a cargo airport and other purposes. This option passes through Bureau of Land Management lands, going south through mining areas along the California/Nevada state line and then turns northwest, skirting private land around the Sandy Valley community. It crosses two pipeline, two road/highway, and one powerline and telephone rights-of-way. It also passes near the Stateline Wilderness Area.

Continuing along Bureau of Land Management lands just north of Secondary State Route 16, the Stateline Pass Option crosses State Route 160 to intersect the Jean Corridor east of Pahrump. In the Pahrump vicinity, State roads access the national forests to the north, and there are several tracks and trails in the area.

The corridor then crosses from Clark County into Nye County before splitting, with the corridor passing close to the Town of Pahrump and the Pahrump Valley Alternate passing closer to the Spring Mountains east of Pahrump. The corridor segment crosses several parcels of private property. The alternate segment abuts the Toiyabe National Forest and a Bureau of Land Management utility corridor and then enters the utility corridor. The corridor and alternate segments rejoin near the community of Johnnie, just east of State Route 160. There are several tracks and trails in this area. The corridor continues to the north until it passes just south of U.S. 95, where it turns northwest through Bureau of Land Management land north of the Ash Meadows National Wildlife Refuge [approximately 14 kilometers (9 miles) west of Johnnie].

Continuing to the north across the Amargosa Desert, the corridor crosses State Route 160, several gravel roads, and a number of two-track roads on Bureau of Land Management land. The corridor crosses a Bureau utility corridor, two telephone, and two powerline rights-of-way. It then crosses U.S. 95 and enters Nevada Test Site property northeast of the Town of Amargosa Valley and continues to the proposed repository site at Yucca Mountain.

Valley Modified. About 53 percent of the lands associated with the Valley Modified Corridor are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in DIRS 103079-BLM (1998, all).

The U.S. Air Force uses about 11 percent of the lands associated with the Valley Modified Corridor. The corridor crosses Nellis Air Force Base northeast of Las Vegas and the Nellis Air Force Range near Indian Springs. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 32 percent of the lands associated with the Valley Modified Corridor. The corridor enters the Nevada Test Site near Mercury, traveling northwest to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

The Fish and Wildlife Service manages about 3 percent of the lands associated with the Valley Modified Corridor as part of the Desert National Wildlife Refuge, which was established in 1936 for the protection and preservation of desert bighorn sheep. Portions of this refuge overlap the Nellis Air Force Range and are controlled jointly by the Air Force and the Fish and Wildlife Service. Use and public access to the joint-use area of the Desert National Wildlife Range and Nellis Air Force Range are restricted by a memorandum of understanding (DIRS 103472-USAF 1999, Appendix C). The Valley Modified corridor passes potential Wilderness Study Areas under consideration by Congress. The Quail Springs Wilderness Study Area, and the Nellis Air Force Range A, B, and C Wilderness Study Areas, located on Bureau of Land Management lands, were inventoried under the 1976 Federal Land Policy and Management Act in support of the 1964 Wilderness Act. Wilderness Study Areas cannot be altered unless they have been released from the program. At this time, there has been no action to release these areas.

The Valley Modified Corridor begins along the Union Pacific rail line in the Apex/Las Vegas area of Clark County, Nevada (Chapter 2, Figure 2-26). The corridor has two possible starting locations and two possible variations, until they merge north of the City of Las Vegas in the Apex area. Clark County is proposing an industrial park on lands transferred from the Bureau of Land Management that would encompass the primary corridor origination location. The Valley Connection starting segment begins in a Bureau corridor near private property in the vicinity of the City of North Las Vegas and travels along the Union Pacific rail line toward Apex until it turns west. The alternate segment crosses three powerline rights-of-way before turning to the west.

After the corridor turns west from either starting location, there are again two options--the corridor itself and the Sheep Mountain Option slightly north of the corridor. Both the corridor and the alternate cross Bureau of Land Management lands and then enter the Nellis Small Arms Range. After leaving the Small Arms Range, they cross the Nellis Air Force Range Wilderness Study Areas A, B, and C and then pass through the Desert National Wildlife Range and the Quail Springs Wilderness Study Area. Both cross several gravel and two-track roads, some of which enter the Desert National Wildlife Range to the north. The corridor and alternate merge before the corridor crosses the Wildlife Range and the Quail Springs Wilderness Study Area a second time. A powerline follows U.S. 95 from its intersection with State Route 157 to Mercury, where it enters the Nevada Test Site.

After the corridor and alternate join, the corridor continues to the northwest through the Las Vegas Valley, passing northeast of U.S. 95 and just to the north of Floyd Lamb State Park and the Las Vegas Paiute Reservation. It crosses several roads and two-track roads that lead into the Desert National Wildlife Range. Continuing to the northwest and running just north of U.S. 95, the corridor crosses an area close to the Desert National Wildlife Range, Desert View Natural Environmental Area, and Nellis Air Force Range.

The corridor then splits east of Indian Springs, with both segments continuing west and crossing from Clark County into Nye County east of Mercury. The northern segment (the corridor) bypasses Indian Springs and Cactus Springs, running to the north across the Desert National Wildlife Range and Bureau of Land Management lands until it merges with the southern segment just south of Mercury. The corridor crosses existing roads and tracks in the area south of Mercury, in the vicinity of Desert Rock.

The Indian Hills Alternate passes south of U.S. 95 across Bureau of Land Management lands until it crosses back to the north of U.S. 95 and joins the corridor south of Mercury. After the routes join, the corridor enters DOE property just southwest of Mercury and continues south of Skull Mountain to Yucca Mountain.

3.2.2.1.2 *Air Quality and Climate*

This section contains information on the existing air quality in areas through which the candidate rail corridors pass. It also provides background on the general climate in those areas.

Air Quality. The Caliente, Carlin, Caliente-Chalk Mountain, and Jean Corridors pass through rural parts of Nevada that are either unclassifiable or in attainment for criteria pollutants (DIRS 148123-EPA 1999, all; DIRS 149905-EPA 1999, all; DIRS 149906-EPA 1999, all; DIRS 149907-EPA 1999, all). There are no State air-quality monitoring stations in these corridors (DIRS 103404-Bureau of Air Quality 1999, pp. A1-1 through A1-9).

The Valley Modified Corridor crosses central Clark County at the north end of the Las Vegas Valley and continues in a northwest direction toward the Nevada Test Site. The air quality in the part of the corridor that passes through the Las Vegas Valley and extends part of the way to Indian Springs is in nonattainment for particulate matter with a diameter of less than 10 micrometers (PM_{10}). Clark County adopted a revised implementation plan in 2001 for demonstrating PM_{10} attainment (DIRS 155557-Clark County 2001, Executive Summary) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration of the 24-hour standard from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. A decision has not been made on the county's request for an extension to the attainment period. The Environmental Protection Agency has acknowledged the request, but has not yet completed its formal review of the revised implementation plan (DIRS 156896-Davis 2001, all).

In addition, the Las Vegas Valley air basin is in nonattainment for the 3-hour carbon monoxide standard, largely the result of vehicular emissions. Clark County adopted a State Implementation Plan for carbon monoxide to achieve the attainment criteria by December 2000 (DIRS 156706-Clark County 2000, all). The Plan outlines a methodology to maintain acceptable carbon monoxide concentrations through transportation planning and control measures. The Environmental Protection Agency has deemed the motor vehicle carbon monoxide estimates indicated in the Plan *adequate* (65 *FR* 71313; November 30, 2000). In 2000, monitoring results indicated that the Plan criteria has been met (DIRS 157158-EPA 2000, all); however, the area is still officially classified as in nonattainment.

Climate. There are two general climate descriptions for the five rail corridors: one for the three corridors that approach the Yucca Mountain site from the north and one for the two corridors that approach the site from the south or southeast. The Caliente, Carlin, and Caliente-Chalk Mountain Corridors approach from the north and cross a number of mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nye County the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches); annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters

(2 inches) an hour can occur in the summer. Each of the three corridors approaching Yucca Mountain from the north pass through central Nye County, and DOE believes that the climate described is a reasonable average for conditions along these corridors.

The Jean and Valley Modified Corridors approach the Yucca Mountain site from the south where precipitation is generally between 10 and 20 centimeters (4 and 8 inches) per year and snowfall is rare. Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52).

3.2.2.1.3 *Hydrology*

This EIS discusses hydrologic conditions in terms of surface water and groundwater.

3.2.2.1.3.1 Surface Water. Researchers studied the alternative rail corridors for their proximity to sensitive environmental resources, including surface waters and riparian lands (DIRS 104593-CRWMS M&O 1999, Appendixes E, F, G, H, and I). The goal in planning the corridors was to avoid springs and riparian lands by 400 meters (1,300 feet) if possible. Table 3-37 summarizes potential surface-water-related resources along the candidate corridors. It lists resources within the 400-meter corridor or within a 1-kilometer (0.6-mile) region of influence along the corridor. Table 3-38 presents similar information for the variation segments. The last column of Table 3-37 identifies water resources that DOE would avoid by using a specified variation rather than the corresponding segment along the rail corridor. Water resources along the variation segment that would be "substituted" can be linked from Table 3-38. If the same water resource would be in proximity to both the corridor and variation segment, it is marked as "Avoided" in Table 3-37, but appears again in Table 3-38 for the variation.

Potential hydrologic hazards along the rail corridors include flash floods and debris flow. All corridors have potential flash flooding concerns. DOE would design and build a rail line that would be able to withstand a 100-year flood event safely.

Appendix L of this environmental impact statement is a floodplain/wetland assessment for the proposed repository action, including the Nevada transportation routes. This appendix includes the results of efforts to identify flood zones along the potential rail corridors and their associated alternate segments through the use of Flood Insurance Rate Maps published by the Federal Emergency Management Agency. The flood zone maps do not provide complete coverage for any of the rail corridors primarily because there are none for the large areas of the Nevada Test Site and the Nellis Air Force Range. In some areas the maps do, however, provide a good indication of 100-year flood zones that might exist in the rail corridors. Consistent with the distribution of surface-water resources listed in Table 3-37, the floodplain information in Appendix L (see Table L-4) indicates the greatest number of different flood zones would occur along the Caliente and Carlin Corridors.

3.2.2.1.3.2 Groundwater. Groundwater basins that the candidate rail corridors cross represent part of the potentially affected environment. As described for groundwater in the immediate region of Yucca Mountain (Section 3.1.4.2.1), the State of Nevada has been divided into groundwater basins and sub-basins. The sub-basins are called hydrographic areas. A map of these areas (DIRS 101486-Bauer et al. 1996, p. 543) was overlain with a drawing of the proposed rail corridors to produce a reasonable approximation of the areas that would be crossed by each corridor. Table 3-39 lists results of this effort for the rail corridors. Table 3-40 presents similar information for the different segments associated with the corridor variations. The tables also list estimates of the perennial yield for each hydrographic area crossed and if the area is a State Designated Groundwater Basin [a hydrographic area in which the permitted water rights approach or exceed the estimated perennial yield and the water resources are depleted or require additional administration, including a State declaration of preferred uses (municipal

Table 3-37. Surface-water-related resources along candidate rail corridors[a] (page 1 of 2).

Rail corridor	Distance from corridor (kilometers)[b]	Feature	Avoided by variation (Yes or No)[c]
Caliente			
Eccles Siding to Meadow Valley Wash	Within	Riparian area/stream – corridor crosses and is adjacent to stream and riparian area in Meadow Valley Wash	Y-1, 2
Meadow Valley to Sand Spring Valley	1.0	Spring – Bennett Spring, 3.2 kilometers southeast of Bennett Pass	N
	0.05 - 2.6	Springs – group of five springs (Deadman, Coal, Black Rock, Hamilton, and one unnamed) east of White River	N
	Within	Riparian/river – corridor parallels (and crosses) the White River for about 10 kilometers. August 1997 survey found river to be mostly underground with ephemeral washes above ground.	N
	0.8	Spring – McCutchen Spring, north of Worthington Mountains	N
Sand Spring Valley to Mud Lake	0.02	Spring – Black Spring, south of Warm Springs	N
Mud Lake to Yucca Mountain	Within - 2.5	Springs – numerous springs and seeps along Amargosa River in Oasis Valley	Y-8
	Within - 0.3	Riparian area/stream – designated area east of Oasis Valley, flowing into Amargosa River, also riparian area, with persistent water and extensive wet meadows near springs and seeps	Y-8
	0.3 - 1.3	Springs – group of 13 unnamed springs in Oasis Valley north of Beatty	Y-8
Carlin			
Beowawe to Austin	0.5	Spring – Tub Spring, northeast of Red Mountain	Y-11
	0.8	Spring – Red Mountain Spring, east of Red Mountain	Y-11
	0.9	Spring – Summit Spring, west of corridor and south of Red Mountain	N
	0.4	Spring – Dry Canyon Spring, west of Hot Springs Point	N
	0.8	Spring – unnamed spring on eastern slope of Toiyabe Range, southwest of Hot Springs Point	N
	1.0	Riparian area – intermittent riparian area associated with Rosebush Creek, in western Grass Valley, north of Mount Callaghan	Y-12
	Within	Riparian/creek – corridor crosses Skull Creek, portions of which have been designated riparian areas	Y-12
	Within	Riparian/creek – corridor crosses intermittent Ox Corral Creek; portions designated as riparian habitat. An August 1997 survey found creek dry with no riparian vegetation present	Y-12
	0.1	Spring – Rye Patch Spring, at north entrance of Rye Patch Canyon, west of Bates Mountain	N
	Within	Riparian area – corridor crosses and parallels riparian area in Rye Patch Canyon	Y-13
	0.7	Spring – Bullrush Spring, east of Rye Patch Canyon	N
Austin to Mud Lake	0.8	Springs – group of 35 unnamed springs, about 25 kilometers north of Round Mountain on east side of Big Smoky Valley	Y-14
	0.6	Riparian area – marsh area formed from group of 35 springs	Y-14
	0.6	Spring – Mustang Spring, south of Seyler Reservoir	Y-14
	0.3	Riparian/reservoir – Seyler Reservoir (seasonal), west of Manhattan	Y-14

Table 3-37. Surface-water-related resources along candidate rail corridors[a] (page 2 of 2).

Rail corridor	Distance from corridor (kilometers)[b]	Feature	Avoided by variation (Yes or No)[c]
Carlin (continued)			
Mud Lake to Yucca Mountain		See Caliente corridor	
Caliente-Chalk Mountain			
Eccles Siding to Meadow Valley		See Caliente corridor	
Meadow Valley to Sand Spring Valley		See Caliente corridor	
Sand Spring Valley to Yucca Mountain	1.0	Spring – Reitman's Seep, in eastern Yucca Flat, east of BJ Wye	Y-15, 16
	0.8	Spring – Can Spring, on north side of Skull Mountain on Nevada Test Site	Y-15
Jean		None identified	
Valley Modified		None identified	

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).
b. To convert kilometers to miles, multiply by 0.62137.
c. Some water resources would be avoided by corridor variations. These are identified with a "Y" (yes) and a number representing the specific variation from Table 3-38 that avoids the specific resource. Table 3-38 identifies the variation by number and shows the water resources associated with the corridor segment unique to that variation. The same water resource might be in proximity to both the rail corridor and variation segment. In such cases, the resource is marked "Avoided" for the rail corridor here, but appears on Table 3-38 for the variation.

and industrial, domestic supply, agriculture, etc.)] (DIRS 103406-NDWP 1992, p. 18). These are the areas where additional water demand would be most likely to produce an adverse effect on local groundwater resources. Table 3-39 indicates that none of the corridors would completely avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain Corridor would cross only two Designated Basins, one at Panaca Valley near the start of the corridor and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain Corridors split.

The last column of Table 3-39 identifies hydrographic areas that DOE would avoid or cross differently if a corridor variation (also identified in the table) were to be used. In most cases, the variation listed in Table 3-40 would have little or no effect on the hydrographic areas crossed. The Crestline Option, Caliente Option, White River Alternate, Goldfield Alternate, and Stateline Pass Option would involve changing, dropping, or adding a single hydrographic area to those that the rail corridor would cross. The Monitor Valley Option is the only other variation that would make a difference and would result in changing two and adding one to the list of hydrographic areas that the Carlin Corridor would cross.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-11 for the hydrographic areas in the Yucca Mountain region. For simplicity, the perennial yield values listed in Table 3-39 generally come from a single source (DIRS 103406-NDWP 1992, Regions 4, 10, 13, and 14) and, therefore, do not show a range of values for each area. The hydrographic areas in the Yucca Mountain region (that is, areas 225 through 230) are the exception to perennial yield values from the single source. The perennial yield values for these areas are from DIRS 147766-Thiel (1999, pp. 6 to 12), which compiles estimates from several sources. The table lists the lowest values in that document.

The perennial yield value shown for Area 227A is the lowest estimated value presented in DIRS 147766-Thiel (1999, p. 8) and is further divided into 300 acre-feet (370,000 cubic meters) for the eastern third of the area and 580 acre-feet (720,000 cubic meters) for the western two-thirds.

Table 3-38. Surface-water-related resources along unique segments of corridor variations.[a,b]

Variation	Applicable corridor(s)[c]	Water resource features: Distance from corridor (kilometers)[d]	Water resource features: Feature
1. Crestline Option	CL/CM	0.3	Spring - Miller Spring south of SR[e] 319 and southeast of Panaca; important water source for game
		1.0	Spring - Miser Spring south of SR 319 and southeast of Panaca
		Within	Riparian area/stream - variation crosses Meadow Valley Wash stream and riparian area south of Panaca
2. Caliente Option	CL/CM	Within	Riparian area/stream - variation crosses Meadow Valley Wash stream and riparian area south of Caliente
		0.6	Spring - unnamed spring in Caliente
		Within	Spring - unnamed spring in Meadow Valley north of Caliente
		0.5	Springs - two unnamed springs in Meadow Valley north of Caliente
3. White River Alternate	CL/CM		None identified - parallels White River further than rail corridor, but not within 1 kilometer
4. Garden Valley Alternate	CL/CM		None identified
5. Mud Lake Alternate	CL/CR		None identified
6. Goldfield Alternate	CL/CR	0.6	Spring - Tognoni Springs northeast of Goldfield
		0.4	Spring - unnamed spring south of Mud Lake and east of U.S. 95
7. Bonnie Claire Alternate	CL/CR		None identified
8. Oasis Valley Alternate	CL/CR	0.5 - 3.0	Springs - numerous springs and seeps along Amargosa River in Oasis Valley
		Within - 0.3	Riparian area/stream - designated area east of Oasis Valley, flowing into Amargosa River, also a riparian area, with persistent water and extensive wet meadows near springs and seeps
		0.8 - 1.8	Springs - group of 13 unnamed springs in Oasis Valley north of Beatty
9. Beatty Wash Alternate	CL/CR		None identified
10. Crescent Valley Alternate	CR		None identified
11. Wood Spring Canyon Alternate	CR		None identified
12. Steiner Creek Alternate	CR	Within	Riparian area - variation crosses designated riparian area in Water Canyon northeast of Bates Mountain
		Within	Riparian/creek - variation crosses Steiner Creek, a designated riparian area. An August 1997 survey found creek dry and lacking riparian vegetation
13. Rye Patch Alternate	CR	0.1	Riparian area - variation parallels riparian area in Rye Patch Canyon
14. Monitor Valley Option	CR	0.7	Spring - unnamed spring east of variation and east of Toquima Range
		0.2	Riparian area - designated riparian area west of variation, northwest of Belmont. An August 1997 survey found area dry and lacking riparian vegetation.
15. Topopah Option	CM	0.6	Spring - Whiterock Spring north of variation, south of Burnt Mountain
15a. Area 4 Alternate	CM		None identified - avoids Whiterock Spring of the Tonopah Option
15b. Mine Mountain Alternate	CM		None identified - main portion of option still passes Whiterock Spring
16. Mercury Highway Option	CM		None identified
17. Pahrump Valley Alternate	J		None identified
18. Stateline Pass Option	J		None identified
19. Valley Connector	VM		None identified
20. Sheep Mountain Alternate	VM		None identified
21. Indian Hills Alternate	VM		None identified

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).
b. Rail corridors are listed in Table 3-37. Water resources identified in that table that can be avoided by a variation are identified with a number designation that is consistent with the numbering in this table.
c. Rail corridor abbreviations used in the table are defined as follows: CL = Caliente; CM = Caliente-Chalk Mountain; CR = Carlin; J = Jean; VM = Valley Modified.
d. To convert kilometers to miles, multiply by 0.62137.
e. SR = State Route.

Table 3-39. Hydrographic areas (groundwater basins) crossed by candidate rail corridors.

Rail corridor	Hydrographic area[a] No.	Hydrographic area[a] Name	Perennial yield (acre-feet)[b,c,d]	Designated Groundwater Basin[e,f]	Avoided by variation (Yes or No)[g]
Caliente					
Eccles Siding to Sand Spring Valley	204	Clover Valley	1,000	No	Y-1, 2
	203	Panaca Valley	9,000	Yes	Y-1, 2
	181	Dry Lake Valley	2,500	No	N
	208	Pahroc Valley	21,000	No	Y-3
	171	Coal Valley	6,000	No	Y-3
	172	Garden Valley	6,000	No	N
Sand Spring Valley to Mud Lake	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes	N
	173A	Railroad Valley, southern part	2,800	No	N
	156	Hot Creek	5,500	No	N
	149	Stone Cabin Valley	2,000	Yes	N
	141	Ralston Valley	6,000	Yes	Y-6
Mud Lake to Yucca Mountain	145	Stonewall Flat	100	No	Y-6
	144	Lida Valley	350	No	N
	146	Sarcobatus Flat	3,000	Yes	N
	228	Oasis Valley	1,000	Yes	N
	229	Crater Flat	220	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Carlin	54	Crescent Valley	16,000	Yes	N
Beowawe to Austin	138	Grass Valley	13,000	No	N
	137B	Big Smoky Valley, northern part	65,000	Yes	Y-14
Austin to Mud Lake – Via Big Valley	137A	Big Smoky Valley and Tonopah Flat	6,000	Yes	Y-14
	142	Alkali Spring Valley	3,000	No	Y-14
	145 to 227A	See Caliente Corridor			
Mud Lake to Yucca Mountain					
Caliente-Chalk Mountain	204 to 170	See Caliente Corridor			
Eccles Siding to Sand Spring Valley	158A	Emigrant Valley and Groom Lake Valley	2,800	No	N
Sand Spring Valley to Yucca Mountain	159	Yucca Flat	350	No	N
	160	Frenchman Flat	16,000	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Jean	165	Jean Lake Valley	50	Yes	Y-18
Jean to Yucca Mountain	164A	Ivanpah Valley, northern part	700	Yes	Y-18
	163	Mesquite Valley (Sandy Valley)	2,200	Yes	Y-18
	162	Pahrump Valley	12,000	Yes	N
	230	Amargosa Desert	24,000	Yes	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Valley Modified	212	Las Vegas Valley	25,000	Yes	N
Dike Siding (north of Las Vegas) to Yucca Mountain	211	Three Lakes Valley, southern part	5,000	Yes	N
	161	Indian Springs Valley	500	Yes	N
	225	Mercury Valley	250	No	N
	226	Rock Valley	30	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N

a. Source: DIRS 101486-Bauer et al. (1996, pp. 542 and 543 with corridor map overlay).

b. Source: DIRS 103406-NDWP (1992, Regions 4, 10, 13, and 14), except hydrographic areas 225 through 230 for which the source is DIRS 147766-Thiel (1999, pp. 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet (30 million cubic meters) for the combined area of hydrographic areas 225 through 230.

c. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.

d. To convert acre-feet to cubic meters, multiply by 1,233.49.

e. Source: DIRS 148165-NDWP (1999, Regions 4, 10, 13, and 14).

f. "Yes" indicates the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.

g. Some variations would involve crossing different hydrographic areas than those listed here for the rail corridor. In such cases, the portion of the rail corridor that corresponds to the unique variation segment is identified with a "Y" (yes) and a number representing the variation(s) from Table 3-40. Hydrographic areas in which the unique variation segment begins or ends appear both here, with a "Y," and in Table 3-40 with the applicable variation.

h. The perennial yield value shown for Area 227A is the lowest estimated value presented in DIRS 147766-Thiel (1999, p. 8) and is further broken down into 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 720,000 cubic meters (580 acre-feet) for the western two-thirds.

Table 3-40. Hydrographic areas crossed by unique segments of corridor variations.

	Variation	Applicable corridor(s)[a]	Note[b]	Hydrographic area crossed[c] No.	Name	Perennial yield (acre-feet)[d,e]	Designated Groundwater Basin[d]
1.	Crestline Option	CL/CM		197	Escalante Desert	1,000	No
				203	Panaca Valley	9,000	Yes
2.	Caliente Option	CL/CM		203	Panaca Valley	9,000	Yes
3.	White River Alternate	CL/CM		208	Pahroc Valley	21,000	No
				207	White River Valley	37,000	No
				171	Coal Valley	6,000	No
4.	Garden Valley Alternate	CL/CM	(1)	171	Coal Valley	6,000	No
				172	Garden Valley	6,000	No
5.	Mud Lake Alternate	CL/CR	(1)	141	Ralston Valley	6,000	Yes
6.	Goldfield Alternate	CL/CR		141	Ralston Valley	6,000	Yes
				142	Alkali Spring Valley	3,000	No
				145	Stonewall Flat	100	No
7.	Bonnie Claire Alternate	CL/CR	(1)	144	Lida Valley	350	No
				146	Sarcobatus Flat	3,000	Yes
8.	Oasis Valley Alternate	CL/CR	(1)	228	Oasis Valley	1,000	Yes
9.	Beatty Wash Alternate	CL/CR	(2)	228	Oasis Valley	1,000	Yes
				229	Crater Flat	220	No
10.	Crescent Valley Alternate	CR	(1)	54	Crescent Valley	16,000	Yes
11.	Wood Spring Canyon Alternate	CR	(1)	54	Crescent Valley	16,000	Yes
12.	Steiner Creek Alternate	CR	(1)	138	Grass Valley	13,000	No
13.	Rye Patch Alternate	CR	(1)	137B	Big Smoky Valley, north	65,000	Yes
14.	Monitor Valley Option	CR		137B	Big Smoky Valley, north	65,000	Yes
				140A	Monitor Valley, north	8,000	No
				140B	Monitor Valley, south	10,000	No
				141	Ralston Valley	6,000	Yes
15.	Topopah Option	CM	(2)	159	Yucca Flat	350	No
				160	Frenchman Flat	16,000	No
				227A	Fortymile Canyon, Jackass Flats	880	No
16.	Mercury Highway Option	CM	(2)	159	Yucca Flat	350	No
				160	Frenchman Flat	16,000	No
17.	Pahrump Valley Alternate	J	(1)	162	Pahrump Valley	12,000	Yes
18.	Stateline Pass Option	J		164A	Ivanpah Valley, north	700	Yes
				163	Mesquite Valley (Sandy Valley)	2,200	Yes
19.	Valley Connector	VM	(2)	212	Las Vegas Valley	25,000	Yes
20.	Sheep Mountain Alternate	VM	(1)	212	Las Vegas Valley	25,000	Yes
21.	Indian Hills Alternate	VM	(2)	211	Three Lakes Valley, south	5,000	Yes
				161	Indian Springs Valley	500	Yes

a. Rail corridor abbreviations used in the table are defined as follows: CL = Caliente; CM = Caliente-Chalk Mountain; CR = Carlin; J = Jean; VM = Valley Modified.

b. Notes:
1. The corresponding portion of the rail corridor passes over the same hydrographic area(s) for approximately the same distance(s).
2. The corresponding portion of the rail corridor passes over the same hydrographic area(s), but for slightly different distance(s).

c. Source: DIRS 101486-Bauer et al. (1996, pp. 542 and 543 with corridor map overlay).

d. Source: DIRS 103406-NDWP (1992, pp. 21 to 25), except hydrographic areas 225 through 230 for which the source is DIRS 147766-Thiel (1999, pp. 6 to 12).

e. To convert acre-feet to cubic meters, multiply by 1,233.49.

3.2.2.1.4 *Biological Resources and Soils*

3.2.2.1.4.1 Biological Resources. The following sections describe biological resources along each of the candidate rail corridors. These environments include habitat types and springs and riparian areas located in a 400-meter (1,300-foot)-wide corridor along each route. Springs and riparian areas are important because they provide habitat for large numbers of plants, animals, and insects. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, all).

Caliente. From the beginning of the corridor at Caliente to Mud Lake, the Caliente Corridor crosses Meadow, Dry Lake, Coal, Garden, Sand Spring, Railroad, Reveille, Stone Cabin, and Ralston Valleys. From Mud Lake, the corridor crosses Stonewall and Sarcobatus flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. The valleys and flats along the corridor range in elevation from 900 to 1,800 meters (3,000 to 5,900 feet). The corridor also crosses through passes or foothills of several mountain ranges including the Highland, Seaman, Golden Gate, Worthington, and Kawich mountain ranges at elevations ranging from 1,600 to 1,900 meters (5,200 to 6,200 feet). The Caliente Corridor is in the southern Great Basin from its beginning at Caliente to near Beatty Wash. The land cover types along this portion of the corridor include salt desert scrub (60 percent) and sagebrush (33 percent). South of Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-22). Table 3-41 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Caliente Corridor. Unless specifically identified otherwise, the text does not describe resources along the corridor variations (that is, options and alternates).

The only resident threatened or endangered species in the Caliente Corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in this area is low in relation to other areas in the range of the species in Nevada (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). Southwestern willow flycatchers *(Empidonax traillii extimus)*, an endangered species, have been observed in dense stands of riparian vegetation in Lincoln County, but there is no suitable habitat for this species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

The Railroad Valley springfish (*Crenichthys nevadae*), which is Federally threatened and State protected (Nevada Administrative Code 503.067) occurs in Warm Springs about 3 kilometers (1.9 miles) north of the corridor in Hot Creek Valley (DIRS 103261-FWS 1996, all).

Three other species classified as sensitive by the Bureau of Land Management occur in the corridor. Unnamed subspecies of the Meadow Valley Wash speckled dace (*Rhinichthys osculus* ssp.) and Meadow Valley Wash desert sucker (*Catostomus clarki* ssp. 2) have been found in Meadow Valley Wash north of Caliente. In the Beatty area, the Nevada sanddune beardtongue (*Penstemon arenarius*) has been found on sandy soils 10 kilometers (6 miles) north of Springdale. Though not listed in the table, a number of bats classified as sensitive by the BLM also may occur along the corridor and the southern end of the corridor is in the range of the chuckwalla (*Sauromalus obesis*).

The Caliente Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 101523-BLM 1994, Maps 9 through 13). The corridor crosses bighorn sheep (*Ovis canadensis*) habitat west of Goldfield near Stonewall Mountain. It also crosses mule deer use areas in or near the Chief/Delamar, Worthington, Quin Canyon, Reveille, and Kawich mountain ranges. The corridor crosses pronghorn antelope (*Antilocapra americana*) habitat in the Railroad/Reveille, Sandspring, Stone Cabin, and Ralston Valleys; Ralston Range; and north of Goldfield. Parts of Meadow Valley Wash north of Caliente are classified as waterfowl and quail habitat, and the corridor crosses another area classified as quail habitat at the north end of the Chief Range.

At least four springs or groups of springs and three streams or riparian areas are within 0.4 kilometer (0.25 mile) of the corridor (DIRS 104593-CRWMS M&O 1999, Appendix E). These might be wetlands or other waters of the United States, as defined in the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Black Spring is near the corridor at the north end of the Kawich Range and an unnamed spring is near the corridor at the north end of the North Pahroc Range. A series of springs is in the corridor near the Amargosa River in Oasis Valley. The corridor crosses the Meadow Valley Wash south of Panaca. The corridor also crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 10 kilometers (6 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock

Table 3-41. Biological resources in or near the Caliente Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Caliente rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Railroad Valley springfish		1
Sensitive species or habitat		
Amargosa toad		5
Eastwood milkvetch		1
Fringed myotis		1
Funeral Mountain milkvetch		1
Hawk nesting area		1
Meadow Valley Wash desert sucker	1	
Meadow Valley Wash speckled dace	1	
Needle Mountain milkvetch		3
Nevada Sanddune beardtongue	1	1
Oasis Valley speckled dace		2
Oasis Valley springsnail		1
Game habitat		
Bighorn–year round	1	2
Mule deer–winter use	2	
Mule deer–summer use		1
Mule deer–year round	3	1
Pronghorn–year round	6	
Quail–crucial	1	
Quail-year round	1	
Waterfowl–crucial	1	
Springs or groups of springs	4[e]	24[f]
Riparian areas	3	1
Herd Management Units	8	
Caliente Option[g]		
Sensitive species		
Welch's catseye		1
Springs or groups of springs	1	4[f]
Crestline Option[g]		
Sensitive species		
Needle Mountain milkvetch		3
Game habitat		
Bighorn sheep–crucial		1
Mule deer–crucial		1
White River Alternate[g]		
Sensitive species		
Pygmy rabbit		1
Welch's catseye		1
Garden Valley Alternate[g]		
Sensitive species		
Welch's catseye		1
Goldfield Alternate[g]		
Springs or groups of springs		2[f]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix E, pp. E-1 to E-12).
b. There are no biological resources unique to the Mud Lake, Bonnie Claire, Oasis Valley, or Beatty Wash Alternates.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
g. Only resources unique to this alignment variation are listed.

waterholes. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management (DIRS 101523-BLM 1994, Maps 14 and 15). The corridor also crosses a number of *ephemeral* streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. Four of the variations (Crestline Option, Caliente Option, Goldfield Alternate, and Oasis Valley Alternate) along the Caliente Corridor would affect the number of, or distance to, associated water resources. Using the Crestline Option, Caliente Option, or Goldfield Alternate would add one spring within 0.4 kilometer (0.25 mile) of the corridor. The Oasis Alternate is close to the same water resources as the corresponding portion of the rail corridor, but it would be farther away from two groups of springs identified near the Amargosa River.

The Caliente Corridor also crosses eight Bureau of Land Management-designated wild horse or wild horse and burro herd management areas (DIRS 101504-BLM 1979, pp. 2-26 through 2-35; DIRS 101523-BLM 1994, Maps 18 and 19). From the beginning of the corridor to Sand Spring Valley, the corridor passes through herd management areas in the Cedar and Chief Ranges. From Sand Spring Valley to Mud Lake, the corridor crosses the Saulsbury, Reveille, and Stone Cabin herd management areas, and from Mud Lake to Yucca Mountain the route crosses the Goldfield, Stonewall, and Bullfrog herd management areas.

Carlin. The Carlin Corridor crosses Crescent and Grass Valleys, then passes through Big Smoky Valley to Mud Lake. From Mud Lake, the corridor crosses Stonewall and Sarcobatus Flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. Elevations along the route range from 900 to 2,200 meters (3,000 to 7,200 feet).

The Carlin Corridor is in the Great Basin from its start in Beowawe to near Beatty Wash. Land cover types along this portion of the corridor are dominated by salt desert scrub (57 percent), sagebrush (28 percent), and greasewood (7 percent). At Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-24). Table 3-42 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Carlin Corridor (without options or alternates) unless specifically identified otherwise.

The only resident threatened or endangered species in the Carlin Corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in the region is low (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411).

Three other species classified as sensitive by the Bureau of Land Management or as protected by Nevada occur along the Carlin Corridor. A ferruginous hawk (*Buteo regalis*) (also classified as protected by Nevada) nesting area is east of Mount Callaghan. The San Antonio pocket gopher (*Thomomys umbrinus curtatus*) has been found in Big Smoky Valley northwest of the San Antonio Mountains. The Nevada sand dune beardtongue has been found in sandy soils 10 kilometers (6 miles) north of Springdale. A number of bats classified as sensitive by the Bureau of Land Management might occur along the corridor, and the southern end of the corridor is in the range of the chuckwalla.

The Carlin Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 103077-BLM 1983, Map 3-1; DIRS 101523-BLM 1994, Maps 9 to 13; DIRS 104593-CRWMS M&O 1999, p. 3-25). The corridor crosses an area designated as sage grouse (*Centrocercus urophasianus*) habitat in western Grass Valley and another at the southeast end of Rye Patch Canyon. The corridor enters pronghorn antelope habitat north of U.S. Highway 50 near Rye Patch Canyon, along most of Big Smoky Valley, and from Mud Lake to Stonewall Mountain. The corridor crosses mule deer habitat on the west side of Grass Valley and bighorn sheep habitat east of Goldfield.

Three springs, five riparian areas, and one reservoir are within 0.4 kilometer (0.25 mile) of the Carlin corridor (DIRS 104593-CRWMS M&O 1999, Appendix F). These areas might be wetlands or other waters of the United States, as defined by the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Rye Patch Spring is on the edge of the corridor at the south end of the Simpson Park Mountains. A series of springs is in the corridor near the Amargosa River in Oasis Valley. Seyler Reservoir is less than 0.3 kilometer (0.2 mile) from the corridor in the south end of Big Smoky Valley. Three of the riparian areas (Skull and Ox Corral Creeks, and Rye Patch Canyon) are along the section of the route between Beowawe and Austin at the south end of Grass Valley. Ox Corral Creek, at the south end of Grass Valley, is ephemeral and has little or no riparian vegetation where the route crosses it. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management. This corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. Five of the variations (Oasis Valley Alternate, Steiner Creek Alternate, Rye Patch Alternate, Monitor Valley Option, and Goldfield Alternate) would affect the number of, or distance to Carlin Corridor water resources. Changes associated with the Oasis Valley and Goldfield Alternates were covered above in the Caliente Corridor discussion. The Rye Patch Alternate would involve no changes to water resources identified in, or within 0.4 kilometer of the rail corridor, but would parallel the riparian area in Rye Patch Canyon rather than cross it. The Steiner Creek Alternate would avoid two riparian areas, but another two would be within this variation. The Monitor Valley Option would represent a major change in the corridor, but with respect to water resources within 0.4 kilometer, it would avoid only Seyler Reservoir and would add a designated riparian area northwest of Belmont in its stead.

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Table 3-42. Biological resources in or near the Carlin Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Carlin rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Sensitive species		
Amargosa toad		5
Big Smoky Valley speckled dace		1
Crescent Dune aegialian scarab		1
Eastwood milkvetch		1
Ferruginous hawk (nesting area)	1	2
Fringed myotis		1
Funeral Mountain milkvetch		1
Nevada Sanddune beardtongue	1	1
Oasis Valley speckled dace		2
Oasis Valley springsnail		1
Pygmy rabbit		1
San Antonio pocket gopher	1	
Game habitat		
Bighorn–year round	1	2
Mule deer–spring	1	3
Mule deer–summer		3
Mule deer–winter		2
Mule deer–year round		3
Pronghorn–summer	1	
Pronghorn–year round	2	
Sage grouse nesting area		1
Sage grouse strutting ground	2	3
Waterfowl		
Springs or groups of springs	3[e]	60[f]
Riparian areas	5	7
Herd Management Units	6	
Wood Spring Canyon Alternate[g]		
Game habitat		
Mule deer–summer		1
Steiner Creek Alternate[g]		
Springs or groups of springs		3[f]
Riparian areas	2	
Rye Patch Alternate[g]		
Springs or groups of springs		1[f]
Monitor Valley Option[g]		
Sensitive species		
Eastwood milkvetch		1
Pygmy rabbit		1
Speckled dace		1
Game habitat		
Elk	1	
Mule deer–spring	1	
Mule deer–winter		3
Pronghorn–winter	1	
Pronghorn–year round	1	
Sage grouse	2	5
Sage grouse–nesting	1	2
Sage grouse–strutting	1	1
Springs or groups of springs		19[f]
Riparian areas	1	5
Herd Management Units	2	
Goldfield Alternate[g]		
Springs or groups of springs	1	1[e]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix F, pp. F-1 to F-16).
b. There are no biological resources unique to the Crescent Valley, Mud Lake, Bonnie Claire, Oasis Valley, or Beatty Wash Alternates.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
g. Only resources unique to this alignment variation are listed.

The corridor crosses two wild horse or wild horse and burro herd management areas between Beowawe and Austin (Mount Callaghan and Bald Mountain), one in Big Smoky Valley (Hickison) and three between Mud Lake and Yucca Mountain (Goldfield, Stonewall, and Bullfrog) (DIRS 103077-BLM 1983, Map 2-4; DIRS 101523-BLM 1994, Maps 18 and 19).

Caliente-Chalk Mountain. The Caliente-Chalk Mountain Corridor begins near Caliente and is identical to the Caliente Corridor from Caliente to Sand Spring Valley, crossing Meadow, Dry Lake, Coal, and Garden Valleys at elevations ranging from 1,400 to 1,600 meters (4,600 to 5,200 feet). This portion of the corridor also crosses through passes or foothills of the Highland, Seaman, Golden Gate, and Worthington mountain ranges at elevations of 1,500 to 1,800 meters (4,900 to 5,900 feet). After splitting from the Caliente Corridor, the Caliente-Chalk Mountain Corridor proceeds south through Sand Spring and Emigrant Valleys, over Groom Pass, and through Yucca and Jackass Flats to Yucca Mountain. The elevation along this portion of the route ranges from approximately 1,100 to 1,700 meters (3,600 to 5,600 feet).

Predominant land cover types between Caliente and Sand Spring Valley include sagebrush (50 percent) and salt desert scrub (47 percent). The vegetation along the route from Sand Spring Valley to Yucca Flat is typical of the southern portion of the Great Basin. From Yucca Flat to Yucca Mountain, the corridor passes through a zone of transition between the Mojave and Great Basin deserts. The predominant land cover types from Sand Spring Valley to the Yucca Mountain site are blackbrush (50 percent), salt desert scrub (31 percent), and sagebrush (9 percent). Table 3-43 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Caliente-Chalk Mountain Corridor (without variations) unless specifically identified otherwise.

Table 3-43. Biological resources in or near the Caliente-Chalk Mountain Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Caliente-Chalk Mountain rail corridor		
Threatened or endangered species		
Desert tortoise		
Sensitive species		
Beatley's scorpionweed		17
Funeral Mountain milkvetch		1
Hawk nesting area		1
Largeflower suncup	1	18
Long-legged myotis		1
Meadow Valley Wash desert sucker	1	
Meadow Valley Wash speckled dace	1	
Needle Mountain milkvetch		3
Oasis Valley springsnail		1
Ripley's springparsley	1	1
Game habitat		
Mule deer–winter	1	
Mule deer–summer		1
Mule deer–year round	2	
Pronghorn–year round	1	
Quail–crucial	1	
Quail–year round	1	
Waterfowl–crucial	1	

Resource	Occurrences[a] In corridor	Occurrences[a] Within 5 km[d]
Springs or groups of springs	1[e]	14[f]
Riparian areas	2	
Herd Management Units	2	
Mercury Highway Option[g]		
Sensitive species		
Hilend's bedstraw		2
Largeflower suncup		2
Ripley's springparsley	2	6
Springs or groups of springs		2[f]
Topopah Option[g]		
Sensitive species		
Clokey's egg milkvetch		2
Hilend's bedstraw		3
Paiute beardtongue		4
Ripley's springparsley		2
Springs or groups of springs		3[f]
Mine Mountain Alternate[g]		
Sensitive species		
Funeral Mountain milkvetch		4
Largeflower suncup		2
Paiute beardtongue		2
Springs or groups of springs		1[f]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix G, pp. G-1 to G-9).
b. There are no biological resources unique to the Area 4 Alternate. Biological resources for the Crestline and Caliente Options can be found in Table 3-41 for the Caliente Corridor.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Only resources unique to this alignment variation are listed.

The only resident threatened or endangered species in the Caliente-Chalk Mountain Corridor is the desert tortoise, which occurs on the Nevada Test Site south of Yucca Flat. This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance is low (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). Southwestern willow flycatchers, an endangered species, have been observed in dense stands of riparian vegetation in Lincoln County, but there is no suitable habitat for this species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

Four species classified as sensitive by the Bureau of Land Management have been found in the corridor. Unnamed subspecies of the Meadow Valley Wash speckled dace and Meadow Valley Wash desert sucker have been found in Meadow Valley Wash. Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) has been reported between Sand Spring Valley and Yucca Mountain in Yucca Flat. The largeflower suncup (*Camissonia megalantha*) has been found in the corridor at three locations in Yucca Flat. Bats classified as sensitive by the Bureau of Land Management also may occur near the corridor. Chuckwalla may occur in suitable habitat on the Nevada Test Site.

The Caliente-Chalk Mountain Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 101504-BLM 1979, pp. 2-26 through 2-35; DIRS 101523-BLM 1994, Maps 9, 10, and 11). The corridor crosses mule deer use areas in or near the Chief and Delamar ranges, Worthington and Quinn Canyon ranges and north of Groom Pass. The corridor crosses pronghorn habitat in Sand Spring and Emigrant Valleys. Parts of Meadow Valley north of Caliente are classified as waterfowl and quail habitat and the corridor crosses another area classified as quail habitat at the north end of the Chief Range.

At least one spring or group of springs and two streams occur within 0.4 kilometer (0.25 mile) of the corridor. These areas might be classified as wetlands or other waters of the United States (DIRS 104593-CRWMS M&O 1999, p. 3-27), as defined in the Clean Water Act, although no formal wetlands delineation has been conducted. An unnamed spring is near the corridor at the north end of the North Pahroc Range. The corridor crosses Meadow Valley Wash south of Panaca. The corridor crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 10 kilometers (6 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. This corridor also crosses a number of ephemeral streams or washes that might be classified as waters of the United States. Two of the variations (Crestline Option and Caliente Option) would affect the number of or distance to, water resources within a 0.4 kilometer (0.25 mile) of the Caliente-Chalk Mountain Corridor. Changes in the list of nearby water resources for both of these options were covered above in the Caliente Corridor discussion.

The Caliente-Chalk Mountain Corridor passes through two wild horse or wild horse and burro herd management areas (DIRS 101504-BLM 1979, pp. 2-42 and 2-43; DIRS 101523-BLM 1994, Maps 18 and 19) in the Cedar Mountains south of Panaca and in the Chief Range west of Panaca.

Jean. The Jean Corridor starts in Ivanpah Valley north of Jean and proceeds west of Wilson Pass to the Pahrump Valley. The corridor continues to the Yucca Mountain site through Pahrump Valley and across the Amargosa Desert and Jackass Flats. This corridor is in the Mojave Desert, with elevations ranging from about 850 to 1,500 meters (2,800 to 4,900 feet).

The predominant land cover types in the corridor are creosote-bursage (59 percent), Mojave mixed scrub (21 percent), and blackbrush (18 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-28). Table 3-44 lists the biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Jean Corridor (without alternates) unless specifically identified otherwise.

The only resident threatened or endangered species in the Jean Corridor is the desert tortoise. The entire corridor is in the range of this species (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). Along most of the corridor, especially the western portions from Pahrump to Yucca Mountain, the abundance of desert tortoises is low (DIRS 101840-Karl 1980, pp. 75 to 87; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). However, some areas crossed by the corridor in Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have a higher abundance of tortoises (DIRS 101521-BLM 1992, Map 3-13). The corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

One location of each of two subspecies of the pinto beardtongue (*Penstemon bicolor bicolor* and *P.b. roseus),* which is classified as sensitive by the Bureau of Land Management, is in the first 5 kilometers (3 miles) of the corridor near Jean. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters (*Heloderma suspectus cinctum*), and a number of bat species classified as sensitive probably occur there in suitable habitat.

The Jean Corridor crosses several areas the Bureau of Land Management designates as game habitat (DIRS 103079-BLM 1998, Maps 3-7, 3-8, and 3-9). The corridor crosses chukar habitat north of Goodsprings, and quail habitat northwest of Wilson Pass, east of Pahrump, and northwest of Johnnie. The corridor crosses mule deer winter habitat around Wilson Pass and north of Pahrump. The southern edge of bighorn sheep winter range is crossed in the southern Bird Spring Mountains and crucial bighorn habitat is crossed around Wilson Pass. The corridor also crosses a bighorn sheep migration route between the Bird Springs and Spring Mountains and a potential migration corridor from winter range in the Devils Hole Hills to historic but currently unoccupied habitat at the west end of the Spring Mountains.

Table 3-44. Biological resources in or near the Jean Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Jean rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Sensitive species		
Allen's big-eared bat		1
Death Valley beardtongue		3
Desert bearpoppy		3
Fringed myotis		1
Gila monster		1
Long-legged myotis		1
Oasis Valley springsnail		1
Pinto beardtongue	2	18
Redheaded sphecid wasp		1
Sheep fleabane		1
Spring Mountain milkvetch		2
Townsend's big-eared bat		1
White-margined beardtongue		5
Wolly sage		1
Yuma myotis		1
Game habitat		
Bighorn sheep–crucial	1	1
Bighorn sheep–migration corridor	2	
Bighorn sheep–winter	1	7
Chukar–crucial	1	
Mule deer–summer crucial		2
Mule deer–winter	2	2
Quail–crucial	3	4
Springs or groups of springs		11[e]
Herd Management Units	3	
Stateline Pass Option[f]		
Sensitive species		
White-margined beardtongue		1
Pinto beardtongue		1
Desert bearpoppy		7
Rusby's globemallow		1
Pahrump Valley buckwheat		3
Game habitat		
Bighorn sheep–winter	1	
Quail–crucial		2

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix H, pp. H-1 to H-9).
b. There are no biological resources unique to the North Pahrump Valley Alternate.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
f. Only resources unique to this alignment variation are listed.

There are no springs, perennial streams, or riparian areas within 0.4 kilometer (0.25 mile) of this corridor or its variations. The corridor crosses a number of ephemeral washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

There are three wild horse and burro herd management areas in the corridor (DIRS 103079-BLM 1998, Map 2-1). The Red Rock herd management area is southeast of the Spring Mountains and the Wheeler Pass and Johnnie herd management areas are west of the Spring Mountains.

Valley Modified. The Valley Modified Corridor begins in the northeastern corner of the Las Vegas Valley, crosses the northern edge of the valley south of the Las Vegas Range, and continues northwest toward Indian Springs. The route continues across the southern portion of Three Lakes and Indian Springs Valleys to the Nevada Test Site and passes through Mercury Valley, Rock Valley, and Jackass Flats to the Yucca Mountain site. The corridor ranges in elevation from approximately 700 to 1,100 meters (2,300 to 3,600 feet).

This route is in the Mojave Desert and the predominant land cover types are creosote-bursage (79 percent) and Mojave mixed scrub (16 percent; DIRS 104593-CRWMS M&O 1999, p. 3-29). Table 3-45 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Valley Modified Corridor (without alternatives) unless specifically identified otherwise.

The only resident threatened or endangered species in the Valley Modified Corridor is the desert tortoise. The entire corridor is in the range of this species (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). In general, the abundance of tortoises along this corridor through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). This corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95). The razorback sucker (*Xyrauchen texanus*), classified as threatened under the

Table 3-45. Biological resources in or near the Valley Modified Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Valley Modified rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Pahrump poolfish		2
Razorback sucker		1
Sensitive species		
Beatley's scorpionweed		1
California bearpoppy		17
Death Valley beardtongue		2
Desert bearpoppy		11
Largeflower suncup		3
Mojave milkvetch		1
Parish's scorpionweed	3	6
Pinto beardtongue		2
Ripley's springparsley	1	1
Townsend's big-eared bat		1
White-margined beardtongue		1
Game habitat		
Bighorn sheep–crucial		1
Bighorn sheep–winter		3
Mule deer–winter		1
Quail–crucial		2
Springs or groups of springs		3[e]
Indian Hills Alternate[f]		
Sensitive species		
Desert bearpoppy		1
Mojave milkvetch		4
Herd Management Units	1	

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix I, pp. I-1 to I-6).
b. There are no biological resources unique to the Sheep Mountain Alternate or Valley Connector.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
f. Only resources unique to this alignment variation are listed.

Endangered Species Act and as protected under Nevada Administrative Code, have been introduced into ponds at Floyd Lamb State Park, 4.2 kilometers (2.6 miles) south of the corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29). Refuge populations of the Pahrump poolfish (*Empetrichthys latos latos*), classified as endangered under the Endangered Species Act and Nevada Administrative Code, have been introduced into ponds in Floyd Lamb State Park and into the outflow of Corn Creek Springs, 4.5 kilometers (2.8 miles) northeast of the corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29).

Two other species classified as sensitive by the Bureau of Land Management occur in the corridor. Three populations of Parish's scorpionweed (*Phacelia parishii*) and a population of Ripley's springparsley have been reported on the Nevada Test Site in Rock Valley. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters, and a number of bat species probably occur there in suitable habitat.

There are no herd management areas, Areas of Critical Environmental Concern, or designated game habitat in the Valley Modified Corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29; DIRS 103079-BLM 1998, Maps 3-7, 3-8, and 3-9). No springs or riparian areas occur within 0.4 kilometer (0.25 mile) of this rail corridor or its variations. This corridor crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

3.2.2.1.4.2 Soils. Soil surveys have been performed and documented throughout much of the United States, including portions of Nevada, by the U.S. Department of Agriculture. Further, the Department of Agriculture has undertaken several efforts to compile this soil survey data into computerized databases for use by government agencies and the general public. One of these databases, the State Soil Geographic database, was developed by generalizing more detailed soil survey data; its purpose is to support planning on the State and multicounty level (DIRS 154246-USDA 1994, pp. 1 and 2). The Yucca Mountain

Project has queried the database for information on soils along the rail corridors. Though the database presents generalized, or higher level information, it still contains massive amounts of data, much more than can be presented in this EIS. However, DOE selected several soil characteristics with potential for environmental impact implications for presentation here to indicate the types of soil along the corridors. One of the database elements selected was soil areas designated as prime farmland. Prime farmlands are defined as lands that have the best combination of physical and chemical characteristics needed to economically produce sustained high-yield agricultural crops [7 CFR 657.5(a)]. Based on the query of the State Soil Geographic database, there are no soils classified as prime farmlands in the rail corridors, including the option and alternate segments (DIRS 155600-Sorensen 2001, p. 2).

DOE also queried the database for other codes representing soil attributes that could be of concern from an environmental perspective and that would need to be considered during the design and construction of a new branch rail line. The query was made by overlaying the rail corridor locations on the soil units in the database and the result was the identification, by corridor segment, of whether the identified attribute might be present in the area in or around the segment. The selected soil attributes in this query are termed "shrink swell," "erodes easily," "unstable fill," and "blowing soil." Each of these attributes not only represents potential environmental and construction concerns, but is associated with physical characteristics of soil. The following paragraphs describe these attributes.

The *shrink swell* attribute is a gauge of how much the volume of a soil changes when it is wet compared to when it is dry. In the State Soil Geographic database, any soil that swells less than 3 percent when wet is considered to have "low" limitations with respect to its use in construction; 3 to 6 percent is considered to present "moderate" limitations and greater than 6 percent has "high" limitations [DIRS 155602-USDA 2001, Part 620.05(a)(2) and Table 620-2]. Querying the database for the shrink swell code identifies (but does not distinguish) soils with moderate or high limitations. The purpose of these limitations is not to indicate that construction cannot or should not be performed in such soils, but rather that the design and construction plans need to account for that soil characteristic. A soil's potential for volume change with loss or gain of moisture varies with the amount and type of clay minerals it contains. In general, more clay in the soil indicates a greater volume change.

The *erodes easily* attribute is a measure of the susceptibility of bare soil to be detached and moved by water. It is based on a factor (designated as "K") used in the commonly employed Universal Soil Loss Equation [DIRS 155602-USDA 2001, Part 620.04 and 620.06(f)(9)]. Measurements on standardized plots are used to determine experimentally values for K, which range from 0.02 to 0.64. Other factors in the equation being equal, a higher K value indicates more susceptibility to erosion by water. The main properties affecting this attribute are soil texture, organic material structure, and permeability. In general, clay soils have low K values because they are resistant to detachment, and sandy soils have low values because they have high infiltration rates (reduced runoff) and particles that erode are not easily transported. Silt loam soils have moderate to high K values. Silt soils have the highest values because they readily form crusts that promote runoff and the particles are easily detached and transported (DIRS 155601-USDA 2001, all). Querying the database for the *erodes easily* code identifies soils with K values greater than 0.35. These are soils with fair to poor erosion characteristics when disturbed and that probably contain relatively high amounts of loams and silts.

The *unstable fill* attribute is a measure of a soil's tendency to move when it is wet or loaded, or both. Stable soils are generally not subject to mass movement under these conditions, and moderately stable soils can involve mass movement when a moderate disturbance provides the initiating action. In unstable soils, slight disturbances can result in mass movement when soil is wet or loaded [DIRS 155602-USDA 2001, Part 620.12(a)(1) and Table 620-37]. Soils identified in the database with the *unstable fill* code are those likely to be moderately stable or unstable when used as fill.

The *blowing soil* attribute is based on groupings used during soil surveys to classify the susceptibility of soil to wind erosion. This classification method uses eight groupings. Soils assigned to group 1 are the most susceptible to wind erosion and those assigned to group 8 are the least susceptible. Descriptions of soils in the groupings range from sands to coarse fragments not susceptible to wind erosion (DIRS 155602-USDA 2001, Part 618.72 and Exhibit 618-16). Querying the database for the blowing soil code identifies soils with wind erodibility groups of 1 or 2 [DIRS 155602-USDA 2001, Part 620.06(f)(9) and Table 620-11]. The definitions of these two groups are as follows:

- Group 1 - Coarse sands, sands, fine sands, and very fine sands

- Group 2 - Loamy coarse sands, loamy sands, loamy fine sands, loamy very fine sands, ash material and sapric (fine, decomposed, organic muck) soil material

The blowing soil attribute identifies areas where fine textured, sandy materials probably predominate and where uncontrolled soil disturbance could result in increased wind erosion.

The following paragraphs discuss the results of the State Soil Geographic database query for the four identified soil attributes by rail corridor. In general terms, the corridors that approach Yucca Mountain from the north (that is, the Caliente, Carlin, and Caliente-Chalk Mountain Corridors) encounter relatively high percentages of soils with *shrink swell*, *erodes easily*, and *blowing soil* characteristics. The corridors that approach Yucca Mountain from the south (that is, the Jean and Valley Modified Corridors) encounter relatively high percentages of soils with only two of those characteristics (that is, *shrink swell* and *blowing soil*). None of the corridors would have high percentages of *unstable fill*, though such soil is present in about 10 percent of the Jean Corridor. The corridor-specific soil information presented in the following paragraphs does not represent detailed soil survey data, but does provide insight into the soil characteristics and potential environmental aspects that would have to be considered during the engineering and design of a branch rail line. Should a decision be made to select one of the rail corridors for transportation of materials to Yucca Mountain, DOE would perform soil surveys of the selected corridor to collect detailed information on the environmental and engineering characteristics of the soils that would be encountered.

Caliente Corridor. Table 3-46 lists the percentage of the Caliente Corridor that crosses soils with the four attributes described in this section. The percentage is the portion of the corridor in which the identified soil attribute could present a concern or limitation for the construction of a rail line. The *shrink swell*, *erodes easily*, and *blowing soils* attributes are prevalent along this corridor. Soils with shrink swell and erodes easily attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, pp. 15 and 16). The *blowing soil* attribute is associated with soils scattered heavily throughout the State (DIRS 155600-Sorensen 2001, p. 18). The corridor crosses no soil areas identified with the *unstable fill* attribute. As indicated in the table, the use of any of the alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 3 percent.

Table 3-46. Percentage of the Caliente Corridor with selected soil attributes.[a]

	Percentage of corridor with identified soil attribute			
Description	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Caliente Corridor	61	69	0	81
Change with any other alternate/option	± 3	± 3	± 0	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Carlin Corridor. Table 3-47 lists the percentage of the Carlin Corridor that crosses soils with the four attributes described in this section. The *shrink swell, erodes easily*, and *blowing soils* attributes are prevalent along this corridor. Soils with *shrink swell* and *erodes easily* attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, p. 15 and 16). The *blowing soil* attribute is associated with soils scattered throughout the State (DIRS 155600-Sorensen 2001, p. 18). The Carlin Corridor would cross no soil areas identified with the *unstable fill* attribute. If the Monitor Valley option was used, the soil attribute percentages would change little with the exception of the *shrink swell* attribute, which would increase by

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Table 3-47. Percentage of the Carlin Corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Carlin Corridor	56	69	0	88
With Monitor Valley Option	76	69	0	84
Change with any other alternate/option	± 2	± 3	± 0	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

about 20 percent. As indicated in the table, the use of any of the other alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 3 percent.

Caliente-Chalk Mountain. Table 3-48 presents the percentage of the Caliente-Chalk Mountain rail corridor that would cross soils with the four attributes described in this section. As can be seen in the table, the *shrink swell, erodes easily,* and *blowing soils* attributes are prevalent along this rail corridor as they are for the other two corridors that would approach the site from the north. Soils with *shrink swell* and *erodes easily* attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, pp. 15 and 16). The *blowing soil* attribute is associated with soils scattered heavily throughout the state (DIRS 155600-Sorensen 2001, p. 18). The Caliente-Chalk Mountain rail corridor would cross no soil areas identified with the *unstable fill* attribute. As shown in the table, use of any one of the other alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 4 percent.

Table 3-48. Percentage of the Caliente-Chalk Mountain rail corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Caliente-Chalk Mountain rail corridor	52	75	0	86
Change with any single alternate/option	± 4	± 3	± 0	± 2

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Jean Corridor. Table 3-49 lists the percentage of the Jean Corridor that would cross soils with the four attributes described in this section. The *shrink swell* and *blowing soils* attributes are prevalent along this corridor even though these soils occur only in scattered locations in southern Nevada (DIRS 155600-Sorensen 2001, pp. 16 and 18). A small amount of this corridor passes through soil areas with *erodes easily* and *unstable fill* attributes. As indicated in the table, if DOE used the Stateline Pass Alternate, the percentage of the corridor crossing soils with *erodes easily* and *blowing soil* attributes would increase about 10 percent for either attribute. Use of the Pahrump Alternate would result in little or no change in the corridor's soil attributes.

Table 3-49. Percentage of the Jean Corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Jean Corridor	89	11	10	77
With Pahrump Valley Alternate	89	11	10	78
With the Stateline Pass Alternate	92	19	11	91

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Valley Modified Corridor. Table 3-50 lists the percentage of the Valley Modified Corridor that crosses soils with the four attributes described in this section. The *shrink swell* and *blowing soils* attributes are prevalent along this corridor, even though these soils occur only in scattered locations in southern Nevada (DIRS 155600-Sorensen 2001, pp. 16 and 18). This corridor would not pass through any significant amount of soil area with *erodes easily* and *unstable fill* attributes. As indicated in the table, if DOE used

Table 3-50. Percentage of the Valley Modified rail corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Valley Modified Corridor	76	0	0	76
With the Indian Hills Alternate	92	0	0	92
Change with any other alternate	± 1	± 0.2	± 0.2	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

the Indian Hills Alternate, the percentage of the corridor crossing soils with *shrink swell* and *blowing soil* attributes would increase about 16 percent for either attribute. Use of either of the other two alternates (Valley Connector or Sheep Mountain) would result in little change in the corridor's soil attributes.

3.2.2.1.5 *Cultural Resources*

The baseline environmental conditions presented in this section focus on the archaeological and historic resources associated with the candidate rail corridors. This section also discusses Native American interests in relation to two of the corridors. Unless otherwise noted, this information is from the *Environmental Baseline File for Archaeological Resources* (DIRS 104997-CRWMS M&O 1999, all). In addition, information from the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all) and *Additional Baseline Cultural Resources Data for the Nevada Transportation Scenario* (DIRS 155826-Nickens and Hartwell 2001, all) were used.

Archaeological and Historic Resources. Based on a records search at the Desert Research Institute in Las Vegas and Reno, the Harry Reid Center at the University of Nevada, Las Vegas, and the Bureau of Land Management Battle Mountain and Elko Offices, archaeological surveys have been conducted in less than 1 percent of the total areas for the Caliente, Jean, and Valley Modified Corridors, less than 3 percent of the total area for the Carlin Corridor, and less than 5 percent of the total area for the Caliente-Chalk Mountain Corridor. The record searches examined each candidate rail corridor, including the variations. Although it is possible to identify areas in a corridor that are most likely to contain cultural resources based on such factors as general land forms and proximity to water, these predictions are highly uncertain prior to corridor selection and the completion of intensive field studies and, therefore, are not included in this EIS.

Initially, archaeological site file searches were completed for larger rail corridors, ranging between 1.6 and 8 kilometers (1 and 5 miles) in total width. More than 2,300 archaeological and historic sites were documented for these wider corridors. The wider corridors used in the initial records searches included all corridor variations. As project plans become more detailed, it was possible to reduce the potential corridor width to a 0.2-kilometer (0.1-mile)-wide buffer zone on either side of the centerline. Records indicate that a number of archaeological sites have been identified along the reduced corridors and that some of these sites are recorded as potentially eligible for nomination to the *National Register of Historic Places*. Table 3-51 summarizes this information. The table also lists potentially eligible sites by type. For conservatism, this group includes sites not yet evaluated for eligibility. The sites recorded but not included in the potentially eligible group represent sites that had no recommendations about eligibility to the National Register.

DOE is implementing the stipulations and forms of a Programmatic Agreement (DIRS 104558-DOE 1988, all) with the Advisory Council on Historic Preservation to address DOE's responsibilities under Sections 106 and 110 of the National Historical Preservation Act and the Council's implementing regulations. Although not a formal signatory to the Agreement, the Nevada State Historic Preservation Officer has the right at any time, upon request, to participate in monitoring DOE compliance with the Programmatic Agreement. In addition, DOE provides annual reports to the Advisory Council on Historic

Table 3-51. Number of previously recorded archaeological sites along candidate rail corridors including variations [based on corridor width of 0.4 kilometer (0.25 mile)].

Category[a]	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Potentially eligible for nomination					
Temporary camps	--[b]	--	3	--	--
Extractive localities	--	--	3	--	--
Processing localities	--	--	--	--	--
Localities	--	1	16	--	--
Caches	--	--	--	--	--
Stations	--	--	--	--	--
Historic sites	--	--	3	--	--
Unknown type	7	20	3	--	7
Total potentially eligible	*7*	*21*	*28*	*0*	*7*
Not evaluated	29	26	6	2	4
Recorded sites (approximate total)	*97*	*110*	*100*	*6*	*19*

a. Section 3.1.6 contains the definitions of site types for potentially eligible for nomination sites (temporary camps, extractive localities, etc.).
b. -- = none identified.

Preservation and the Nevada State Historic Preservation Officer describing the activities conducted by DOE each year to implement the stipulations of the Programmatic Agreement. This report includes a description of DOE coordinations and consultations with Federal and State agencies and Native American tribes concerning historic and culturally significant properties at Yucca Mountain.

DOE will continue to seek input from the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation, and will interact appropriately to meet the reporting and other stipulations of the existing Programmatic Agreement. Because the 1988 Programmatic Agreement primarily covers site characterization activities at the Yucca Mountain site, DOE would negotiate a new programmatic agreement to cover cultural resources requirements for any selected Nevada transportation corridor.

Records and literature reviews reveal the presence of numerous historic properties and districts that one or more of the candidate rail corridors could affect, depending on the route selected. A number of these are linear features that a given corridor would intersect. Table 3-52 lists the more important of these linear properties.

In addition to the linear historic properties, the candidate rail corridors are close to several other historic properties, many of which are already listed on either the *Nevada State Register of Historic Places* or the *National Register of Historic Places*, or are currently unevaluated. Table 3-53 lists the more important properties.

Other potentially important historic properties that could be within rail corridors include elements of many historic mining districts, several historic ranches (especially Crescent, Grass, Big Smoky, and Monitor Valleys), and the World War II Tonopah Army Air Field bombing range. Numerous Cold War-era resources that have been documented at the Nevada Test Site could be affected (for example, Camp Desert Rock).

Native American Interests. Through the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations, Native Americans have noted that, while transportation issues are of extreme interest to them, at present they cannot provide specific comments on any of the Nevada transportation project alternatives (DIRS 102043-AIWS 1998, pp. 4-4 to 4-6) due to the absence of systematic ethnographic studies for any of the proposed project areas.

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Table 3-52. Historic period linear cultural resource properties intersected by potential rail corridors and variations.[a]

Property	Rail corridor-variation	National Historic Trail Designation Status[b]
California Emigrant Trail (1840s)	Carlin	Designated *California National Historic Trail.* Segment is designated Low Potential.[c]
Western Pacific Railroad (1907)	Carlin	
Salt Lake to San Francisco Transcontinental Airways Route (1920-1940s) and Parran to Beowawe Cutoff (1928-1929)	Carlin	
Jedidiah Smith Exploration Route (1827)	Carlin - Monitor Valley Option	
John C. Fremont Military Reconnaissance Route (1845-1846)	Carlin - Big Smoky Valley Option	
James Simpson Federal Wagon Road Route Survey (1859)	Carlin and Monitor Valley Options	
Pony Express Trail (1861)	Carlin and Rye Patch Alternates and Monitor Valley Option	Designated *Pony Express National Trail.* Segment is designated High Potential.[c]
Pacific Telegraph Line (1861)	Carlin and Rye Patch Alternate	
Butterfield Overland Mail & Stage Route (1861)	Carlin and Rye Patch Alternate	
Lincoln Highway (1920s)	Carlin and Rye Patch Alternates and Monitor Valley Option	
Tonopah-Goldfield Railroad (1903-1947)	Carlin/Caliente	
Las Vegas and Tonopah Railroad (1905-1918)	Carlin/Caliente Valley Modified and Indian Hills and Sheep Mountain Alternates	
Jayhawker's Emigrant Trail (1849)	Caliente/Caliente-Chalk Mountain	
Old Spanish Trail (1830); later the Mormon Road (after 1850)	Jean and Stateline Pass Option	Under evaluation for designation by Congress as a National Historic Trail
Yellow Pine Mining Company railroad (1911-1934)	Jean	
Las Vegas to Bullfrog Stage Road (1904-1906)	Carlin Valley Modified - Indian Hills Alternate	
Caliente and Pioche Railroad (1907)	Caliente and Caliente and Crestline Options	

a. Source: DIRS 155826-Nickens and Hartwell (2001, pp. 15 and 20 to 25).
b. Those properties showing no status entries are neither designated by Congress as National Historic Trails nor under evaluation for such a status.
c. Trail segments are evaluated for their potential to afford a high-quality recreation experience in a portion of the route having greater than average scenic values or affording an opportunity to vicariously share the experience of the original users of the trail. Evaluations shown here apply to the trail segment intersected by the applicable rail corridor.

Table 3-53. Cultural resource properties close to proposed rail corridors and listed on State or National Registers of historic places.[a]

Property	Rail corridor	Status
Tonopah Multiple Resource Area	Carlin/Caliente	NRHP
Belmont Historic District	Carlin – Monitor Valley Option	NSRHP, NRHP
Goldfield Historic District	Carlin/Caliente and Goldfield Alternates	NRHP
Union Pacific Depot, Caliente	Caliente	NRHP
Smith (Scott) Hotel, Caliente	Caliente	NSRHP
Sedan Crater Area 10, Nevada Test Site	Caliente-Chalk Mountain	NRHP
Goodsprings Mining District	Jean	NSRHP
Tule Springs Archaeological Site	Valley Modified	NSRHP, NRHP
Corn Creek Campsite	Valley Modified	NRHP
Tule Springs Ranch District	Valley Modified	NRHP

a. Source: DIRS 155826-Nickens and Hartwell (2001, Table 6, pp. 17-19).
b. NRHP = *National Register of Historic Places*; NSRHP = *Nevada State Register of Historic Places.*

General concerns for potential transportation-related impacts raised by Native Americans include the following:

- Radioactive and hazardous waste transportation could have an adverse impact along rail or highway routes near existing or planned Native American communities, people, businesses, and resources.
- All of the proposed routes being considered pass through the traditional holy lands of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples.
- Many of these routes correspond or are adjacent to ancient pathways and complex trail systems known to and used by Native American peoples.
- The Consolidated Group of Tribes and Organizations is aware of important culturally sensitive areas, traditional use areas, sacred sites, and other important resources that fall in the proposed transportation project areas, and will present this information when appropriate in the development of the Nevada transportation system.

These general concerns apply to the proposed rail corridors discussed in this section, and the proposed heavy-haul truck route alternatives and intermodal transfer station locations discussed in Section 3.2.2.2.5.

There are three known historic period Native American cemeteries, two in Crescent Valley and one to the south in Grass Valley. One of the Crescent Valley cemeteries is still in use and is about 1.6 kilometers (1 mile) east of the corridor; the other smaller, early historic cemetery is possibly located within the corridor. The Native American cemetery in Grass Valley might also be located within the corridor. In addition, Western Shoshone families use several hot springs in Crescent Valley for ceremonies. Archaeological investigations in Grass Valley have documented the presence of several historic period Western Shoshone villages, many near ranches that employed Native Americans. For example, at the Grass Valley Ranch, which the Carlin route passes, there are six known villages, several of which might be in the Carlin corridor. Late 19th- and 20th-century Native American villages and homes found in association with Euro-American ranches could occur in many of the valleys that the rail corridors pass through. The same might be true at several mining districts that attracted Native Americans with employment opportunities.

Recent Native American field studies (DIRS 156932-AIET 2000, all) have demonstrated the importance of the Wild Horse and Willow Springs areas, which occur on Nellis Air Force Range and Bureau of Land Management lands east of the Town of Goldfield. The combined Carlin-Caliente Corridor passes to the east of the two springs; the Goldfield Alternate passes to the west. The Goldfield Alternate is the closest to either spring, being about 1.2 kilometers (0.7 mile) west of Willow Springs (DIRS 104593-CRWMS M&O 1999, Appendix E, p. E-10).

Native American communities are present near at least two of the candidate rail corridors:

- *Jean.* The Pahrump Paiute Tribe is a non-Federally recognized tribe without a land base. The tribe consists of about 100 Southern Paiute people living in the Pahrump area (see Section 3.1.6.2). Individual members of the tribe live as close as 5 kilometers (3 miles) to the Jean Corridor.

- *Valley Modified.* The Las Vegas Paiute Tribe is a Federally recognized tribe consisting of about 100 people living on two separate tribal parcels in southern Nevada. One parcel near downtown Las Vegas consists of about 73,000 square meters (18 acres) of land with 21 homes, tribal administrative offices, and various tribal businesses. This parcel is about 11 kilometers (7 miles) from the route of the Valley Modified Corridor. The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16 million square meters (4,000 acres) with 12 homes and various business enterprises. This parcel is about 1.6 kilometers (1 mile) from the Valley Modified Corridor.

Congress has assigned trust lands to the Timbisha Shoshone that would directly involve the Carlin and Caliente Corridors. This is the Timbisha Shoshone Tribe Homeland effort, part of which transfers 11 square kilometers (2,800 acres) of Bureau of Land Management land at Scottys Junction to the Secretary of the Interior to hold in trust for the Tribe. This area is within the Tribe's former homeland and several tribal families lived there. The Tribe plans to use this tract for single-family residences and small-scale economic development (DIRS 154121-DOI 2000, Volume I, p. 19). The Bonnie Claire Alternate of both the Carlin and Caliente Corridors passes directly through the tract transferred to the Timbisha Shoshone Tribe.

In addition, private Native American land holdings could be affected along the Carlin corridor. Western Shoshone families own ranches in Crescent Valley, and several allotments were made to Western Shoshone individuals by the U.S. Government from 1919 to 1925 under provisions of the Dawes Allotment Act of 1887. Several of these allotments were in Big Smoky Valley and Monitor Valley.

3.2.2.1.6 *Socioeconomics*

Section 3.1.7 describes the socioeconomic backgrounds of the three counties (Clark, Lincoln, and Nye) most involved in the corridors. The Carlin corridor includes other counties—Esmeralda, Eureka, and Lander—in addition to Nye County. This section contains baseline socioeconomic information for Eureka, Esmeralda, and Lander Counties.

Socioeconomic effects from the construction of a rail line would be small and, for the most part, short-term. Therefore, the socioeconomic information for Esmeralda, Eureka, and Lander Counties is less detailed than the information for the counties in the repository site region of influence in Section 3.1.7.

Population. Section 3.1.7.1 contains population data on Clark, Lincoln, and Nye Counties. This section provides population background for the other counties potentially affected by the Carlin Corridor (Esmeralda, Eureka, and Lander).

The population of Esmeralda County is 100 percent rural. The 1990 Census population for the county was about 1,300 persons. The 2000 population density of the county is somewhat less than 0.3 person per square mile. The estimated Esmeralda County population in 2000 was about 970 (DIRS 155872-Bureau of the Census 2000, County Totals).

The population of Eureka County is 100 percent rural. The 1990 Census population of the county was about 1,500. The estimated population of Eureka County in 2000 was about 1,650 (DIRS 155872-Bureau of the Census 2000, County Totals). The 2000 population density was about 0.4 person per square mile.

The population of Lander County is rural, with a small urbanized population concentrated entirely in Battle Mountain. The 1990 Census population of the county was about 6,300 persons. The estimated population of Lander County in 2000 was about 7,100 (DIRS 155872-Bureau of the Census 2000, County Totals). The county had a 2000 population density of about 1.2 persons per square mile.

Employment. Section 3.1.7.2 contains employment and economic information on Clark, Nye, and Lincoln Counties. Portions of the potential Carlin rail route pass through Esmeralda, Eureka, and Lander Counties. In 2000, Esmeralda, Eureka, and Lander Counties had average labor forces of about 470, 850, and 2,320, respectively, and average unemployment rates of 10.0, 2.6, and 7.7 percent (DIRS 155818-NDETR 2001, all). In 1997, the per capita income of Esmeralda, Eureka, and Lander Counties was about $19,200, $22,000, and $21,000, respectively (DIRS 153928-NDA 2000, all). All three of these counties are small in economic terms.

Housing. Section 3.1.7.4 contains housing data on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are all rural areas. The housing stock of Esmeralda County in 1990 was about 1,000 units, of which about 590 were occupied (DIRS 148097-Bureau of the Census 1998, Esmeralda). There were about 830 units in 2000 (DIRS 155872-Bureau of the Census 2000, all). The housing stock of Eureka County in 1990 was about 820 units, of which about 620 were occupied (DIRS 148097-Bureau of the Census 1998, Eureka). In 2000, there were about 1,000 units (DIRS 155872-Bureau of the Census 2000, Eureka). The housing stock of Lander County in 1990 was about 2,600 housing units, of which about 2,200 were occupied (DIRS 148097-Bureau of the Census 1998, Lander). In 2000, there were about 2,800 units (DIRS 155872-Bureau of the Census 2000, Lander).

Economy. Section 3.1.7.2 contains employment and economic information on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander are very small counties in economic terms. Eureka and Esmeralda Counties derive most of their economic activity from the accommodations and food service industry. Lander County's largest industries are in the retail and wholesale sectors. Like Lincoln County, Esmeralda and Lander have lower per capita incomes than other Nevada counties and chronically high unemployment.

Public Services. Section 3.1.7.5 contains information on public services in Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. County sheriff departments serve Eureka, Esmeralda, and Lander Counties. During the 2000-2001 school term, the Eureka County school district served 305 students, the Lander County district enrolled 1,449 (847 kindergarten through grade 6 and 602 secondary students), and the Esmeralda County school district served 107 students in kindergarten through grade 8. High-school aged students from Esmeralda attended school in Tonopah (Nye County) (DIRS 155820-NDE 2001, "Nevada School Enrollment 2000-2001"). In 1998, Esmeralda had no practicing doctors or dentists, Eureka had a single practicing physician but no dentists, and Lander County had three doctors and two dentists (DIRS 153928-NDA 2000, all).

3.2.2.1.7 *Noise and Vibration*

Most of the proposed rail corridors pass through unpopulated desert with average day-night background sound levels of 22 to 38 A-weighted decibels (dBA). (A-weighted decibels are explained in Section 3.1.9.1.) However, each candidate corridor passes near small rural communities (see Chapter 6, Figures 6-15 through 6-19). Noise levels in rural communities usually range from 40 to 55 dBA. DOE used computerized mapping programs to examine proposed transportation corridors for the presence and proximity to routes that could be designated for the transfer of nuclear material to the Yucca Mountain site. The process involved the examination of computerized maps at very high detail to determine the extent of road grids in communities and major road intersections. The analysis estimated the distance from the proposed rail corridor and the community to determine if the community was in the region of influence for rail transportation.

Caliente. Most of the Caliente Corridor passes through undeveloped Bureau of Land Management land where background noise levels range from 22 to 38 dBA (Table 3-32), influenced primarily by wind. Noise levels of 40 to 55 dBA are present in the rural communities along the corridor including Beatty, Goldfield, Panaca, and Caliente (Table 3-32).

Carlin. The Carlin Corridor, from its origin at Beowawe to its terminus at Yucca Mountain, including the Monitor Valley option and other options south of Tonopah, traverses mostly unpopulated desert. The only town within 1.6 kilometers (1 mile) of the corridor is Hadley at the southern end of Big Smoky Valley (Monitor Valley option). Noise levels of 40 to 55 dBA are present in rural communities near the corridor, including Beatty, Goldfield, Tonopah, Austin, and smaller communities between Tonopah and Battle Mountain (Table 3-32). Occasional noise from military aircraft overflights occurs near the Nellis Air Force Range.

Caliente-Chalk Mountain. Almost half of the 345-kilometer (214-mile) Caliente-Chalk Mountain Corridor is on Nellis Air Force Range or Nevada Test Site land; the remainder is on Bureau on Land Management land. Noise levels of 40 to 55 dBA are present in rural communities along the corridor including Panaca and Caliente (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Jean. The Jean Corridor, with the Stateline option, passes through Bureau of Land Management land and a small section of private land. A large portion of this proposed corridor passes through unpopulated desert. Noise levels of 40 to 55 dBA are present in small communities along the corridor including Amargosa Valley, Goodsprings, Pahrump, and Jean (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Valley Modified. The Valley Modified Corridor, and its various options, begins in the northeast end of the Las Vegas Valley, travels west across Nellis Air Force Base and the southern end of the Desert National Wildlife Range, and then closely parallels U.S. 95 to the vicinity of Mercury (a government installation). Noise levels along stretches of unpopulated desert should range from 22 to 38 dBA, which are typical for a desert environment during calm and windy days (DIRS 101531-Brown-Buntin 1997, p. 7). The corridor would pass 3 kilometers (2 miles) north of Floyd R. Lamb State Park and less than 5 kilometers (3 miles) south of Corn Creek Station, which is part of the Desert National Wildlife Range managed by the Fish and Wildlife Service. Noise levels at the state park and at Corn Creek would probably be only slightly higher than those in an unpopulated desert environment. Noise levels in the northern Las Vegas Valley can be as high as 60 dBA (Table 3-32). Noise levels in Indian Springs, Cactus Springs, and Mercury probably range from 40 to 55 dBA (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Ground Vibration. Railroad construction and the operation of trains transporting materials and nuclear waste in casks have been proposed for several candidate rail corridors. These corridors have been planned to avoid human residences and communities to the extent possible. As a consequence, background levels of ground vibration lack human influence and are small; that is, most likely less than 50 VdB (velocity decibels, a measure of vibration amplitude).

3.2.2.1.8 *Aesthetics*

To assist in the management of public lands under its control, the Bureau of Land Management established land management guidelines based on the visual resources of an area. Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. There are four visual resource classes. Classes I and II are the more highly valued. Class III is moderately valued, and Class IV is of least value. The majority of land in the potential rail corridors is under the jurisdiction of the Bureau of Land Management. The following paragraphs contain aesthetic baseline information for each of the rail corridors. Visual resource classifications described for the rail corridors were obtained from published Bureau of Land Management documents or through conversations with Bureau of Land Management personnel. Scenic quality classifications for lands that would be crossed on the Nevada Test Site were generated by DOE using Bureau of Land Management guidelines. Section 3.1.10 contains more information on the Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (DIRS 105002-CRWMS M&O 1999, all).

Caliente. Section 3.2.2.1.4 describes the environmental setting along the Caliente Corridor. The corridor passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. The corridor crosses mostly Class IV lands, crosses Class III land near Caliente, and crosses or skirts the edges of Class II lands near Caliente and in the Seaman, Reveille and Kawich ranges, the Golden Gate Hills, and the Worthington Mountains. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Carlin. Section 3.2.2.1.4 describes the environmental setting of the Carlin corridor. The corridor passes through four Bureau of Land Management resource areas (Elko, Shoshone-Eureka, Tonopah, and Las Vegas). The route is on Class IV land from its beginning to the Nevada Test Site border. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Caliente-Chalk Mountain. Section 3.2.2.1.4 describes the environmental setting of the Caliente-Chalk Mountain Corridor. The corridor passes through the Caliente and Schell Bureau of Land Management resource areas. The route begins on Class III land east of Caliente, and crosses mostly Class IV land to the border of the Nevada Test Site (Figure 3-31). On the Nevada Test Site the corridor passes through lands with scenic quality Class B or C.

Jean. Section 3.2.2.1.4 describes the environmental setting of the Jean Corridor. The corridor crosses the Las Vegas and the Northern and Eastern Mojave Bureau of Land Management resource areas. The Wilson Pass Option of the corridor passes through Class II land in Goodsprings Valley and the Spring Mountains, but the rest of the route to the west and the Stateline Pass Option cross Class III land. Approximately 10 kilometers (6 miles) of the route crosses lands in California; that area does not have Visual Resource Management class ratings. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Valley Modified. Section 3.2.2.1.4 describes the environmental setting of the Valley Modified Corridor. The corridor crosses the Las Vegas Bureau of Land Management resource area. The entire route to the boundary of the Nevada Test Site crosses Class III land. Lands on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Section 3.2.2.1.1 contains additional information on current land use. Based on these descriptions, all of the candidate rail corridors have been affected to some extent by man. Based on a field survey by DOE, these impacts can be seen from the potential corridors and in detail from the adjacent mountains.

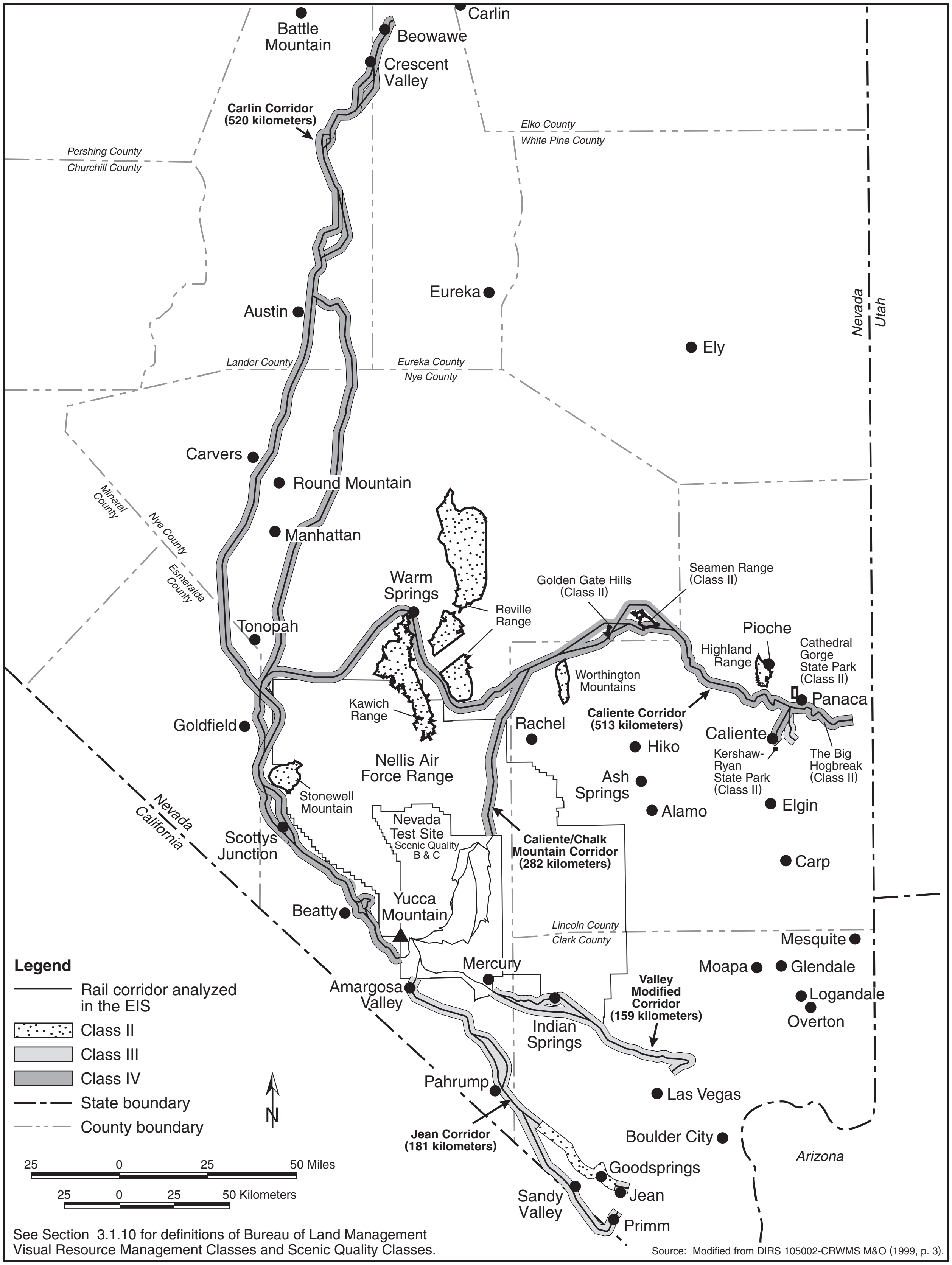

Figure 3-31. Visual Resource Management classes along the potential rail corridors.

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3.2.2.1.9 *Utilities, Energy, and Materials*

All five primary rail corridors pass through typically remote Nevada countryside but are within the southern Nevada supply chain for the commodities required during construction and operation. Electric power, which would be available to a limited extent at nearby communities or other locations near power lines, probably would not be needed.

3.2.2.1.10 *Environmental Justice*

The five candidate rail corridors would not appreciably affect counties other than those through which they pass. Section 3.1.13 contains information on the minority and low-income communities in the three counties most involved in the corridors (Clark, Lincoln, and Nye) and includes Figures 3-27 and 3-28, which show locations of minority and low-income communities, respectively, in Nevada. Figures 3-29 and 3-30 provide similar information, at a higher resolution, for the Las Vegas metropolitan area in Clark County. The Carlin corridor is the only route that passes through other counties (Esmeralda, Eureka, and Lander, in addition to Nye). This section contains baseline information on minority and low-income communities in Esmeralda, Eureka, and Lander Counties, in addition to the information shown in Figures 3-27 and 3-28. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (DIRS 105004-CRWMS M&O 1999, all) is the basis for the information in this section. DOE has updated and refined information germane to the environmental justice analysis since the Publication of the Draft EIS, including an additional and more detailed mapping of minority populations (see Appendix J, Section J.3.1.2). Although 2000 Census data concerning minority communities in Nevada were available at the Census block level in time for the Final EIS analysis, 2000 Census data on low-income communities were not. Therefore, the information on low-income communities is from the most current available source, the 1990 Census.

In 2000, the minority population (White Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo/Aleut, and Other) of Esmeralda County was about 190, or 20 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 6 of Table DP-1; Esmeralda County). In 1990, there were about 210 persons living in poverty, or 15 percent of the population. No block group in Esmeralda County exceeded the threshold for identification as a low-income community (DIRS 103134-Bureau of the Census 1992, Table P117). (Section 3.1.13 defines minority and low-income communities.)

In 2000, the minority population of Eureka County was about 250 persons, or 15 percent (DIRS 156909-Bureau of the Census 2001, p. 7 of Table DP-1; Eureka County). In 1990, there were about 160 persons living in poverty, or 10 percent of the population. No block group in Eureka County exceeded the threshold for identification as a low-income community (DIRS 103141-Bureau of the Census 1992, Table P117).

In 2000, the minority population of Lander County was about 1,400 persons, or 24 percent (DIRS 156909-Bureau of the Census 2001, p. 9 of Table DP-1; Lander County). In 1990, there were about 670 persons living in poverty, or 11 percent of the population. No block group in Lander County exceeded the threshold for identification as a low-income community (DIRS 103144-Bureau of the Census 1992, Table P117).

Some detail on the affected environment for environmental justice that was presented in the Draft EIS for rail corridors has been deleted because of a change in the nature and level of available information. Because of the differences in the level of data between the minority and low-income categories, a combined, parallel discussion is no longer appropriate. The baseline presentation of information now relies on the Section 3.1.13 figures referenced above to identify locations of minority and low-income communities in proximity to the candidate rail corridors.

3.2.2.2 Heavy-Haul Truck Route and Intermodal Transfer Station Environmental Baseline

This section discusses the environmental characteristics of counties and land areas that could be affected by the construction and operation of an intermodal transfer station and the operation of heavy-haul trucks carrying spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository on Nevada highways. The discussion describes existing environmental conditions in the candidate areas where an intermodal transfer station could be located along Nevada highway routes that could be used for the heavy-haul truck transportation of casks containing spent nuclear fuel and high-level radioactive waste. The candidate locations for an intermodal transfer station are near the communities of Caliente, Sloan, and Jean, and northeast of Las Vegas near Dry Lake on the Union Pacific Railroad Valley siding. These locations can be grouped into three general sites near existing rail lines and highways: near Caliente (Caliente), southeast of Las Vegas (Sloan/Jean), and northeast of Las Vegas (Apex/Dry Lake). DOE is considering more than one site for the station in each general area.

The heavy-haul trucks would use existing highways that would be upgraded as necessary to accommodate such vehicles. There are five potential heavy-haul truck routes. Three of these routes (Caliente, Caliente/Chalk Mountain, and Caliente/Las Vegas) are associated with the Caliente intermodal transfer station site. The Sloan/Jean and Apex/Dry Lake intermodal transfer station sites are associated with one candidate route each.

To define the existing (or baseline) environment associated with the three candidate intermodal transfer station locations and along the five candidate heavy-haul truck routes, DOE has compiled environmental information for each of the following subject areas.

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.2.1)
- *Air quality and climate:* The quality of the air and climate (Section 3.2.2.2.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.2.3)
- *Biological resources:* Important biological resources (Section 3.2.2.2.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.2.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.2.6)
- *Noise and vibration:* The existing noise environments (Section 3.2.2.2.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.2.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.2.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.2.10)
- *Existing traffic on potential routes for heavy-haul trucks:* Existing traffic in terms of level of service (on the five alternative heavy-haul truck routes) (Section 3.2.2.2.11)

A Geographic Information System provided population distributions for the different population zones (urban, rural, and suburban) along the alternative highway routes for heavy-haul trucks. This approach, which Chapter 6 and Appendix J describe in detail, differs from the national transportation analysis discussed in Section 3.2.1 and which used the HIGHWAY computer program (DIRS 104780-Johnson et al. 1993, all). DOE expects the waste quantities generated by intermodal transfer station construction to be small in comparison to those from repository construction and operation. Therefore, this discussion does not include existing waste disposal infrastructure along the routes.

DOE evaluated potential impacts of the implementing alternatives in the region of influence for each of the following subject areas. Table 3-54 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict potentially large impacts related to heavy-haul infrastructure construction and operations.

Table 3-54. Regions of influence for heavy-haul implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or for which ownership or use would change as a result of construction and use of an intermodal transfer station and associated highway route
Air quality and climate	The atmosphere in the vicinity of sources of criteria pollutants that would be emitted during construction and operations, and particularly the Las Vegas Valley for implementing alternatives in which the construction and operation of an intermodal transfer station and associated heavy-haul truck route could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards.
Hydrology	*Surface water:* areas where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that would be affected by eroded soil or potential spills of construction contaminants *Groundwater:* aquifers that would underlie areas of construction and operations and that could be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands, that could be disturbed by construction and operation of an intermodal transfer station and associated heavy-haul truck route; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flow
Cultural resources	Land areas that would be disturbed by the construction and operation of an intermodal transfer station and associated heavy-haul truck route
Socioeconomic environments	Clark, Lincoln, Nye, and other counties that a route for heavy-haul vehicles could traverse
Occupational and public health and safety	800 meters[a] on each side of the route for heavy-haul vehicles for incident-free transportation, 80-kilometer[b] radius for potential impacts from accidents
Noise and vibration	Inhabited commercial and residential areas where noise or vibration from the construction and operation of an intermodal transfer station and associated routes for heavy-haul vehicles could be a concern
Aesthetics	The landscapes along potential routes for heavy-haul vehicles and at potential locations for intermodal transfer station where aesthetic quality could be affected by construction and operation
Utilities energy, and materials	Local, regional, and national supply infrastructure that would be required to support construction and operation of an intermodal transfer station and associated route for heavy-haul vehicles
Environmental justice	Locations of minority, low-income, and Native American populations along the heavy-haul truck implementing alternatives; includes the regions of influence for each of the individual subject or impact areas.

a. 800 meters = 0.5 mile.
b. 80 kilometers = 50 miles.

3.2.2.2.1 *Land Use and Ownership*

This section describes existing land use and ownership for the candidate intermodal transfer station locations and for the candidate heavy-haul truck routes. Table 3-55 summarizes the size and ownership of the land parcels DOE considered for each site at the three candidate locations. An intermodal transfer station and support area would require about 0.2 square kilometer (50 acres), so in some cases the ultimate commitment of land would be much less than the parcel size under consideration.

Caliente. DOE has identified two potential locations for an intermodal transfer station southwest of the City of Caliente. Table 3-55 lists the ownership of the land involved. Both sites would use a local road to provide access to U.S. 93, the starting point for all three of the heavy-haul truck routes associated with this intermodal transfer station. Both parcels being considered are in the Rainbow Canyon section of Meadow Valley Wash. This canyon is used for ranching and a variety of recreational purposes and is the route of the Union Pacific railroad. Kershaw-Ryan State Park is across Meadow Valley Wash about 0.4 kilometer (0.25 mile) east of the station sites (DIRS 104873-CRWMS M&O 1997, all). Based on visual observations of the locations, the parcels are currently used as a wastewater treatment facility operated by the City of Caliente. Land near the facility is used for hay production.

Table 3-55. Land areas under consideration for candidate intermodal transfer station sites (square kilometers).[a,b]

	Commitment		
		Percentage current ownership or control[c]	
Potential location	Total area	BLM	City of Caliente[d]
Caliente			
North Site	0.5		100
South Site	0.25		100
Sloan/Jean			
North Site	3.3	100	
Middle Site	3.1	100	
South Site	1	100	
Apex/Dry Lake			
Northwest Site	3.5	100	
Northeast Site	0.18	100	
South Site	0.96	100	

a. Sources: DIRS 104873-CRWMS M&O (1997, all); DIRS 155985-CRWMS M&O (1997, all); DIRS 155984-CRWMS M&O (1997, all); DIRS 155986-CRWMS M&O (1997, all).
b. To convert square kilometers to acres, multiply by 247.1.
c. Bureau of Land Management property is public land administered by the Bureau.
d. "City of Caliente" designates patented land owned by the city. A small undesignated portion of both Caliente sites is Bureau of Land Management land.

Sloan/Jean. DOE has identified three possible parcels in the area of Sloan and Jean for potential use as the location of an intermodal transfer station. Each provides adequate land area adjacent to the Union Pacific mainline and has access to nearby existing roadways. Figure 6-21 in Chapter 6 shows these sites. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. The parcels are currently used for recreation and mining. Detailed information on land use is available in the *Proposed Las Vegas Resource Management Plan and Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

Apex/Dry Lake. DOE has identified three land parcels near the intersection of U.S. 93 and Interstate 15 at the Apex and Dry Lake areas northeast of Las Vegas for the possible location of an intermodal transfer station. Each parcel provides adequate land area close to the Union Pacific mainline and has access to existing roadways. The parcels are crossed by several roads and appear to be used mostly for recreation. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. Detailed information on land use is available in DIRS 103079-BLM (1998, all). The Moapa Indian Reservation is about 5 kilometers (3 miles) north of the proposed station site. The Dry Lake solar enterprise zone is almost 5 kilometers west of the site (DIRS 101811-DOE 1996, p. 4-227). The Apex industrial complex is about 16 kilometers (10 miles) to the southwest. Tenants at the complex include Kerr-McGee Chemical Corporation, Chemstar Inc., and Georgia Pacific Corporation. Silver State Disposal operates a waste landfill and waste-processing facilities east of I-15 about 5 kilometers south of the southernmost site. The Apex area is also proposed for the construction of several new power-generating plants.

Routes for Heavy-Haul Trucks. The five possible routes that heavy-haul trucks could use in Nevada—Caliente, Caliente/Las Vegas, Caliente/Chalk Mountain, Sloan/Jean, and Apex/Dry Lake—have existing highways in established rights-of-way. The routes use combinations of highways that, after improvement, heavy-haul trucks could use to travel from an intermodal transfer station at a mainline railroad to the repository.

3.2.2.2.2 *Air Quality and Climate*

This section summarizes existing air quality and climate conditions for each of the candidate intermodal transfer station sites and the five candidate heavy-haul truck routes.

Air Quality. Both the Caliente and Apex/Dry Lake sites are in areas that are either unclassified or in attainment for criteria pollutants (DIRS 104879-Fosmire 1999, all). The northern portion of the Sloan/Jean site is in the Las Vegas nonattainment area (DIRS 104879-Fosmire 1999, all; DIRS 148123-EPA 1999, all; DIRS 149905-EPA 1999, all; DIRS 149906-EPA 1999, all; DIRS 149907-EPA 1999, all). There are no State of Nevada air quality monitoring stations at or near either the Caliente or Apex/Dry Lake site (DIRS 103404-Bureau of Air Quality 1999, pp. A1-1 through A1-9). Clark County operates a particulate matter (PM_{10}) monitoring station at Jean.

The Caliente and Caliente/Chalk Mountain heavy-haul truck routes both pass through rural parts of Nevada. These areas are either unclassifiable or in attainment for criteria pollutants. The air quality in these areas is good. There are no State of Nevada air quality monitoring stations along these routes (DIRS 103404-Bureau of Air Quality 1999, pp. A1-1 through A1-9). These statements are also true for the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake routes before they enter and after they leave the Las Vegas Valley.

The air quality in the segments of the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake routes that pass through the Las Vegas Valley and extend part of the way to Indian Springs is in serious nonattainment for particulate matter (PM_{10}) (DIRS 149905-EPA 1999, Region 9 PM_{10} Nonattainment Areas). Clark County adopted a revised implementation plan in 2001 for demonstrating PM_{10} attainment (DIRS 155557-Clark County 2001, Executive Summary) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration of the 24-hour standard from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. A decision has not yet been made on the County's request for an extension to the attainment period. The Environmental Protection Agency has acknowledged the request, but has not yet completed their formal review of the revised implementation plan (DIRS 156896-Davis 2001, all).

In addition, the Las Vegas Valley air basin is in nonattainment for the 3-hour carbon monoxide standard, largely the result of vehicular emissions. Clark County adopted a State Implementation Plan for carbon monoxide to achieve the attainment criteria by December 2000 (DIRS 156706-Clark County 2000, all). The Plan outlines a methodology to maintain acceptable carbon monoxide concentrations through transportation planning and control measures. The Environmental Protection Agency has deemed the motor vehicle carbon monoxide estimates indicated in the Plan *adequate* (65 *FR* 71313; November 30, 2000). In 2000, monitoring results indicated that the Plan criteria had been met (DIRS 157158-EPA 2000, all); however, the area is still officially classified as in nonattainment.

Climate. This section describes the climate affecting the candidate intermodal transfer station sites and heavy-haul truck routes.

The community of Caliente and the site of the proposed intermodal transfer station are in Meadow Valley Wash, a relatively narrow canyon that trends to the northeast. Small canyons enter Meadow Valley Wash from the east and west. The diurnal cycle of up-canyon winds during the daytime and down-canyon winds at night minimizes periods of calm conditions. The community of Caliente is about 1,300 meters (4,300 feet) above sea level. Average annual precipitation is about 22 centimeters (9.0 inches); average snowfall is about 35 centimeters (14 inches) (DIRS 100117-CRWMS M&O 1997, p. A-14). The maximum single-day precipitation record is 5.4 centimeters (2.1 inches). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime. The mean maximum July temperature is 35ºC (95ºF), and the mean minimum January temperature is -8.2ºC (18ºF) (DIRS 100117-CRWMS M&O 1997, p. A-14).

The climate at the Sloan/Jean and Apex/Dry Lake station sites is similar to Las Vegas (DIRS 100117-CRWMS M&O 1997, Section 4.1; DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). Precipitation in Las Vegas averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare. Occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime. The maximum recorded daily precipitation is 6.6 centimeters (2.6 inches). The mean maximum July temperature is 40ºC (104ºF), and the mean minimum January temperature is 0.9ºC (33ºF).

The Caliente and Caliente/Chalk Mountain heavy-haul truck routes, and to a lesser extent the Caliente/ Las Vegas route, cross mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nevada the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches) in central White Pine and Nye Counties; annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). The southern portion of the Caliente/Las Vegas route, through Clark County, is at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). Along all three of these routes, occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime.

The Sloan/Jean and Apex/Dry Lake heavy-haul truck routes are at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). However, occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime.

3.2.2.2.3 *Hydrology*

This section describes hydrologic conditions in terms of surface water and groundwater near the candidate intermodal transfer stations and along the candidate heavy-haul shipment routes.

3.2.2.2.3.1 Surface Water. DOE studied each of the candidate intermodal transfer station sites and associated highway routes for their proximity to sensitive environmental resources (DIRS 104593-CRWMS M&O 1999, Appendixes J, K, L, M, N, and O), including surface waters and riparian lands. Table 3-56 summarizes potential surface-water-related resources within a 1-kilometer (0.6-mile) region of influence from the station sites and highway routes that heavy-haul trucks would use. The table lists surface-water-related resources associated with the Caliente intermodal transfer station site and with each of the potential routes starting at that site. No surface-water-related resources were identified in the region of influence for either the Sloan/Jean or Apex/Dry Lake station site, and none were identified along the associated routes.

Table 3-56. Surface-water-related resources at potential intermodal transfer station sites and along candidate routes for heavy-haul trucks.[a]

Station or route	Distance from station or route (kilometers)[b]	Feature
Caliente station	0.5	Spring – unnamed spring, southwest of Caliente and northwest of station site
	0.2	Riparian/stream – perennial stream and riparian habitat along Meadow Valley Wash
Caliente route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.5	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to Rachel	0.01 - 0.07	Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road
Rachel to Yucca Mountain (via Tonopah)	0.03 - 0.02	Riparian area – Twin Spring Slough and Echo Canyon Reservoir, along State Highway 375, east of Warm Springs
	0.2	Springs – Twin Springs, 15 kilometers east of Warm Springs
	Within - 0.2	Springs – Warm Springs, group of thermal springs near town of Warm Springs, outflow crosses the route
	0.4	Spring – Fivemile Spring in Stone Cabin Valley
	1.0	Spring – Rabbit Spring, west of Goldfield
	0.1	Spring – unnamed, in upper Oasis Valley, northwest of Beatty
	0.3	Spring – unnamed, in upper Oasis Valley
	0.4	Spring – unnamed, in upper Oasis Valley, northwest of Beatty
	0.4	Spring – unnamed, east of U.S. 95 in upper Oasis Valley
	0.4	Spring – Fleur-de-lis Spring at Springdale
	0.1	Spring – unnamed, east of U.S. 95 in upper Oasis Valley
	0.1	Spring – unnamed, east of U.S. 95 north of Beatty
	0.9	Spring – unnamed, east of U.S. 95, north of Beatty
	0.9	Spring – Gross Spring, east of U.S. 95, north of Beatty
	Within	River – Amargosa River, parallels U.S. 95 for about 23 kilometers near Beatty
	0.2 - 0.3	Springs – group of thermal springs on east border of U.S. 95, north of Beatty
	0.3	Spring – Well Spring, west of U.S. 95, north of Beatty
	0.4	Spring – Ute Spring, north of Beatty
	0.6	Spring – unnamed, west of U.S. 95, north of Beatty
	0.3	Spring – Revert Spring in Beatty
	0.3	Spring – unnamed, east of U.S. 95, south of Beatty
Caliente/Chalk Mountain Route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.5	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to Rachel	0.01 - 0.07	Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road
Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site)	0.9	Spring – Cane Spring, north of Skull Mountain on Nevada Test Site
Caliente/Las Vegas route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.5	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to I-15 (via U.S. 93)	0.7	Spring – Pedretti Seeps, 3.5 kilometers southeast of Crystal Springs
	0.7	Spring – unnamed, west of route, just south of Pedretti Seeps
	0.8	Spring – Deacon Spring, 5 kilometers southeast of State Highway 375
	1.0	Spring – Brownie Spring, 5 kilometers southeast of State Highway 375
	Within - 0.5	Spring – Ash Springs (76 meters from road), 7 kilometers southeast of State Highway 375, flows under road to Ash Springs Pool and to Pahranagat Creek and irrigation ditches
	0.7	Spring – Grove Spring, 1.5 kilometers north of Upper Pahranagat Valley
	0.1	Lakes – route parallels Upper and Lower Pahranagat lakes and associated inundated areas (marshes) for about 15 kilometers
	0.1	Spring – unnamed, 0.2 kilometers west of U.S. 93 and Maynard Lake
	0.1	Lake – Maynard Lake, route borders for about 1 kilometer
	0.8	Spring – Coyote Springs, 21.5 kilometers north of junction with State Route 168
U.S. 93/I-15 junction to U.S. 95 (via the proposed northern beltway)		None
U.S. 95 to Yucca Mountain		None
Sloan/Jean station		None identified
Sloan/Jean route		None identified
Apex/Dry Lake station		None identified
Apex/Dry Lake route		None identified

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes J, K, L, M, N, and O).
b. To convert kilometers to miles, multiply by 0.62137.

Appendix L of this EIS is a floodplain/wetland assessment for the proposed repository action, including the Nevada transportation routes. With respect to heavy-haul truck routes, the appendix addressed floodplain actions that could be required near the repository site as well as at the intermodal transfer station locations. With respect to the heavy-haul truck routes, the Proposed Action would involve modifications of existing roadways, which should already incorporate appropriate flood design, so no new floodplain issues are expected.

Intermodal Transfer Station Locations

Caliente. Flood Insurance Rate Maps published by the Federal Emergency Management Agency address the area in Meadow Valley Wash south of Caliente where the two proposed sites for the Caliente intermodal transfer stations are located. The maps (DIRS 148130-FEMA 1988, all; DIRS 148131-FEMA 1988, all) show two areas on the west side of the Union Pacific rail tracks that match up with the proposed sites. Both areas are outside the inundation boundary of the 100-year flood, but within the boundary of the 500-year flood.

Sloan/Jean. Based on Flood Insurance Rate Maps, the southernmost site proposed for the Jean intermodal transfer station (on the west site of the Union Pacific rail tracks) would be in the same general area as a 100-year flood inundation zone. The flood map (DIRS 148132-FEMA 1995, all) shows three separate washes or drainage areas that originate in the area northwest of the intersection of State Route 161 (or State Route 53 on the map) and I-15. From their origins, the washes drain to the southeast, beneath I-15, and join a southwest drainage that parallels the rail tracks until it reaches the Roach Lake area to the south. The southern Jean intermodal transfer station site is in the area where the first southeast-draining channel curves around into a southwest-draining channel. The 100-year flood inundation areas appear to be about 150 meters (500 feet) wide for these drainage channels.

The northern site proposed for the Jean intermodal transfer station is on the east side of the tracks in an area where the map shows no inundation lines (DIRS 148132-FEMA 1995, all). In fact, the map identifies this area with a Zone X designation, indicating it is outside the 500-year floodplain.

According to the Federal Emergency Management Agency Map Index for Clark County, Nevada, and Incorporated Areas (DIRS 148133-FEMA 1995, all), the northernmost site for this area, the Sloan intermodal transfer station site, is in an area (Panel 32003C2925 D) with no printed map. The Map Index further describes these unprinted areas as Zone X, indicating they are outside the 500-year floodplain.

Apex/Dry Lake. Based on the Flood Insurance Rate Map for the area of the Apex/Dry Lake intermodal transfer station sites (DIRS 148134-FEMA 1995, all), the three proposed locations are outside any 100-year flood zone. The nearest flood zone identified on the map is for the Dry Lake area west of the sites. At its closest, the inundation area approaches to within about 300 meters (1,000 feet) of I-15, but the intermodal transfer station site would be on the other side (east side) of I-15. The northern site would appear to be at least 300 meters from the inundation zone. All three areas are in Zone X (determined to be outside the 500-year floodplain).

Highway Routes for Heavy-Haul Trucks

Potential hydrologic hazards along a heavy-haul truck route include flash flooding and debris flow. All routes have potential flash flooding concerns. However, because of the required road upgrades, the robustness of the vehicle and shipping cask, and the en route safeguards (for example, escorts), flash flooding or standing water is not expected to be a serious threat to heavy-haul shipments.

3.2.2.2.3.2 Groundwater. As discussed in relation to the potential rail corridors, all of Nevada has been divided into groundwater basins and sub-basins, with these latter, smaller divisions termed hydrographic areas. The water resource planning and management information generated by the State of Nevada for these hydrographic areas provides the basis for groundwater information presented for both intermodal transfer station locations and the candidate highway routes that would be used by heavy-haul trucks. The following paragraphs provide an overview of the groundwater conditions at these sites and along the associated routes. Water demand at an intermodal transfer station would be small for both construction and operations. Water needs during operations would consist primarily of the needs of the personnel that staff the station. Water needs for construction and operations would be met by trucking water to the site, installing a well, or possibly by connection to a local water distribution system. This demand would be unlikely to cause noticeable change in water consumption rates for the area. Consequently, no baseline water-use information is provided.

Intermodal Transfer Station Locations

Caliente. The two sites southwest of Caliente being considered for the intermodal transfer station are close to one another and are located in Nevada's Colorado River Basin (designated Hydrographic Region 13). This hydrographic region covers about 32,000 square kilometers (12,000 square miles) and parts of four counties (DIRS 148165-NDWP 1999, Region 13). The Colorado River Basin is further divided into 27 hydrographic areas including Lower Meadow Valley Wash (Area 205), where the Caliente sites are located. This area has been assigned a "Designated Groundwater Basin" status, which means that its permitted water rights approach or exceed the estimated perennial yield and its water resources are being depleted or require additional administration. The additional administration normally includes a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.) for the groundwater from this area.

Sloan/Jean. The Jean sites being considered for the intermodal transfer station are in Nevada's Central Hydrographic Region (also designated Region No. 10). This is the largest hydrographic region in Nevada, encompassing about 120,000 square kilometers (46,000 square miles) and parts of 13 counties (DIRS 148165-NDWP 1999, Region 10). The Central Region has 90 hydrographic areas and sub-areas, including Ivanpah Valley/Northern Part (Area 164A), where the Jean sites are located. This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater in the vicinity of the candidate Jean sites is approximately 150 meters (490 feet) (DIRS 101933-Thomas, Welch, and Dettinger 1996, Plate 1).

The site near Sloan being considered for the intermodal transfer station is in Nevada's Colorado River Basin (Hydrographic Region 13), as described for the Caliente sites. The Sloan site is in the hydrographic area designated Las Vegas Valley (Area 212). This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater at Sloan is approximately 240 meters (790 feet) (DIRS 101933-Thomas, Welch, and Dettinger 1996, Plate 1).

Apex/Dry Lake. The three sites near Apex/Dry Lake being considered for the intermodal transfer station are close to one another and are in Nevada's Colorado River Basin, as described for the Caliente sites. The Apex/Dry Lake sites are in the hydrographic area designated Garnet Valley (Area 216). The estimated perennial yield for the groundwater in this area is only 490,000 cubic meters (400 acre-feet), but it is not a Designated Groundwater Basin. The depth to groundwater at Apex/Dry Lake is about 60 meters (200 feet) (DIRS 101933-Thomas, Welch, and Dettinger 1996, Plate 1).

Highway Routes for Heavy-Haul Trucks

The highway routes in Nevada that heavy-haul trucks could use cross through several hydrographic regions and a greater number of hydrographic areas. To identify groundwater that could potentially be affected, a map of these hydrographic areas (DIRS 101486-Bauer et al. 1996, p. 543) was overlain with a drawing of the proposed highway routes to get a reasonable approximation of the areas that would be crossed. The results of this effort are listed in Table 3-57. This table also lists estimates of the perennial yield for each of the hydrographic areas crossed and if the area is a Designated Groundwater Basin. Basins with this designation are the areas where additional water demand would be most likely to adversely affect local groundwater resources. None of the candidate routes would totally avoid

Table 3-57. Hydrographic areas (groundwater basins) crossed by candidate routes for heavy-haul trucks.[a]

Route	Hydrographic area Number	Hydrographic area Name	Perennial yield[b,c] (acre-feet)[d]	Designated groundwater basin[e,f]
Caliente				
Caliente to Crystal Springs (near Hiko)	203	Panaca Valley	9,000	Yes
	181	Dry Lake Valley	2,500	No
	182	Delamar Valley	3,000	No
Crystal Springs to Rachel	209	Pahranagat Valley	25,000	No
	169A	Tikaboo Valley, Northern Part	1,300	No
Rachel to Yucca Mountain (via Tonopah)	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes
	173A	Railroad Valley, Southern Part	2,800	No
	173B	Railroad Valley, Northern Part	75,000	No
	156	Hot Creek	5,500	No
	149	Stone Cabin Valley	2,000	Yes
	141	Ralston Valley	6,000	Yes
	137A	Tonopah Flat	6,000	Yes
	142	Alkali Spring Valley	3,000	No
	144	Lida Valley	350	No
	146	Sarcobatus Flat	3,000	Yes
	228	Oasis Valley	1,000	Yes
	230	Amargosa Valley	24,000	Yes
	229	Crater Flat	220	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Caliente/Chalk Mountain				
Caliente to Crystal Springs (near Hiko)	203 to 209	See Caliente Route		
Crystal Springs to Rachel	209 to 170	See Caliente Route		
Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site)	170			
	158A	Emigrant Valley and Groom Lake Valley	2,800	No
	159	Yucca Flat	350	No
	160	Frenchman Flat	16,000	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Caliente/Las Vegas				
Caliente to Crystal Springs (near Hiko)	203 to 209	See Caliente Route		
Crystal Springs (near Hiko) to U.S. 93/I-15 junction at Dry Lake	209			
	210	Coyote Springs Valley	18,000	Yes
	217	Hidden Valley	200	No
U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction	216	Garnet Valley	400	No
U.S. 95 junction to Yucca Mountain	212	Las Vegas Valley	25,000	Yes
	211	Three Lakes Valley, Southern Part	5,000	Yes
	161	Indian Springs Valley	500	Yes
	225	Mercury Valley	250	No
	226	Rock Valley	30	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Sloan/Jean[h]				
Jean to U.S. 95 junction	164A	Ivanpah Valley, Northern Part	700	Yes
	165	Jean Lake Valley	50	Yes
U.S. 95 junction to Yucca Mountain	212 to 227A	See Caliente-Las Vegas route		
Apex/Dry Lake				
U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction	216 to 212	See Caliente-Las Vegas route		
U.S. 95 junction to Yucca Mountain	212 to 227A	See Caliente-Las Vegas route		

a. Source: DIRS 101486-Bauer et al. (1996, pp. 542 and 543 with route map overlay).
b. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
c. Source: DIRS 103406-NDWP (1992, Regions 10, 13, and 14); for Hydrographic Areas 225 through 230 the source is DIRS 147766-Thiel (1999, pp. 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet for the combined area of hydrographic areas 225 through 230 (DIRS 103406-NDWP 1992, Region 14).
d. To convert acre-feet to cubic meters, multiply by 1,233.49.
e. "Yes" indicates that the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield, and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.
f. Source: DIRS 148165-NDWP (1999, Regions 10, 13, and 14).
g. The perennial yield value shown for Area 227A is the lowest estimated value in DIRS 147766-Thiel (1999, p. 8), and is accompanied by the additional qualification: 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 720,000 cubic meters (580 acre-feet) for the western two-thirds.
h. The hydrographic areas listed for the Sloan/Jean Route are based on the intermodal transfer station located at Jean. For the Sloan location, the route would begin with Hydrographic Area 212, then proceed as shown.

Designated Groundwater Basins. However, the Caliente/Chalk Mountain route would cross only two designated basins: one in the Lower Meadow Valley Wash at the beginning of the route and one at Penoyer Valley where the Caliente and Caliente/Chalk Mountain routes split.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-11. For simplicity, the perennial yield values listed in Table 3-57 generally come from a single source (DIRS 103406-NDWP 1992, Regions 10, 13, and 14) and, therefore, are not ranges of values. The hydrographic areas in the vicinity of Yucca Mountain (that is, Areas 225 through 230) are the exception to perennial yield values coming from the single source. The perennial yield values for these areas come from DIRS 147766-Thiel (1999, pp. 6 to 12), which compiles estimates from several sources. The table lists the lowest values presented in that document.

3.2.2.2.4 *Biological Resources*

The existing biological environment described in this section includes the areas inside the boundaries of the intermodal transfer station sites and within 100 meters (about 330 feet) of the centerline of the heavy-haul truck routes. It also includes springs within 400 meters (0.25 mile) of the intermodal transfer sites and the routes. The section discusses environmental settings and important biological resources for each candidate station and associated heavy-haul truck routes. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, all).

Caliente Intermodal Transfer Station

The 0.7-square kilometer (170-acre) area DOE is considering for the Caliente intermodal transfer station is about 1 kilometer (0.6 mile) southwest of Caliente and less than 500 meters (1,600 feet) west of Meadow Valley Wash. This area is at an elevation of about 1,200 meters (3,900 feet). The land cover types at this site are primarily agricultural—pasture, 88 percent, and salt desert scrub, 12 percent.

No species classified as Federally threatened or endangered, as State protected, or as sensitive by the Bureau of Land Management occur in the proposed location of the Caliente intermodal transfer station. Although the Federally endangered Southwestern willow flycatcher has been detected in Meadow Valley Wash, there is no habitat for this species on this site (DIRS 152511-Brocoum 2000, pp. A-9 to A-13). Two fish classified as sensitive by Bureau of Land Management, the Meadow Valley Wash speckled dace (also classified as sensitive by Nevada) and the Meadow Valley Wash desert sucker (*Catostomus clarki* ssp.), occur in the Meadow Valley Wash.

There is no designated game habitat in this area, but the adjacent Meadow Valley Wash is classified as important habitat for Gambel’s quail (DIRS 101504-BLM 1979, pp. 2-34 and 2-35).

There are no springs at the proposed station location, but there are springs adjacent to the site and some areas within the site have soils and plant species indicative of wetlands (DIRS 104593-CRWMS M&O 1999, pp. 3-35 and 3-36). Many of these moist areas are probably the result of irrigation with treated effluent from the wastewater treatment facility within the site, but some might qualify as wetlands or other waters of the United States if they are the result of outflow from nearby springs or the adjacent Meadow Valley Wash. The adjacent perennial stream and riparian habitat along Meadow Valley Wash also might be classified as a wetlands or other waters of the United States, although there has been no formal wetlands delineation.

Caliente Route. This route passes through the southern Great Basin Desert from the beginning of the route in Caliente to near Beatty. From south of Beatty to Yucca Mountain, the route passes through the Mojave Desert. The predominant land cover types along the entire route are salt desert scrub (49 percent), sagebrush (14 percent), and creosote-bursage (13 percent).

Three threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente heavy-haul truck route. The Hiko White River springfish (*Crenicthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (DIRS 103262-FWS 1998, p. 16), which is about 75 meters (250 feet) south of State Route 375 at its intersection with State Route 318, west of U.S. 93. The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). A population of the Railroad Valley springfish (*Crenicthys nevadae*, Federal threatened) has been introduced into Warm Springs, the outflow of which crosses U.S. Highway 6 (DIRS 103261-FWS 1996, p. 20). The southern part of the route, along U.S. 95 from Beatty to Yucca Mountain, is within the range of the desert tortoise (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative number of tortoises in this area is low (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411).

Six species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route. The Pahranagat speckled dace (*Rhinichthys osculus velfier*) occurs in Crystal Springs. The Railroad Valley tui chub (*Gila bicolor* ssp 7) (also classified as sensitive by Nevada) occurs in Twin Spring Slough along State Route 375. The Amargosa toad (*Bufo nelsoni*) and the Oasis Valley speckled dace (*Rhinichthys osculus* ssp 1) (both also classified as protected by Nevada) occur in the Amargosa River and elsewhere in the Oasis Valley. Two bats, the Townsend's big-eared bat (*Corynorhinus townsendii*) and fringed myotis (*Myotis thysanodes*), have been documented near the southern end of the route, and other bats classified as sensitive by the Bureau of Land Management might occur near the route. The chuckwalla lizard also might occur in suitable habitat along the southern end of the route.

This route crosses eight areas designated as game habitat (DIRS 101504-BLM 1979, pp. 2-27 to 2-36; DIRS 101523-BLM 1994, Maps 9, 10, 12, and 13). Portions of Meadow Valley Wash are designated important habitat for Gambel's quail and waterfowl. The route crosses mule deer habitat in Newman Canyon, in the Pahroc Range, in the Pahranagat Range, and northwest of the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range, and pronghorn habitat northwest of the Groom Range and from west of Sand Spring Valley through Railroad, Stone Cabin, and Ralston Valleys.

Nineteen springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be considered wetlands or other waters of the United States under Section 404 of the Clean Water Act, although no formal wetlands delineation has been conducted. The route is adjacent to Meadow Valley Wash at the proposed location of the intermodal transfer station. There is an unnamed spring near U.S. 93 west of Caliente. Crystal Spring and its outflow are about 10 meters (33 feet) from State Route 375, which also passes within 250 meters (820 feet) of Twin and Warm Springs and crosses their outflows. Fivemile Spring is about 0.4 kilometer from U.S. 6 in Stone Cabin Valley. U.S. 95 passes within 0.4 kilometer of 12 springs or groups of springs in the Oasis Valley and along the Amargosa River, and crosses the Amargosa River at Beatty. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route also borders the Bureau of Land Management Oasis Valley Area of Critical Environmental Concern, which is designed to protect riparian areas and sensitive species in Oasis Valley south of Springdale (DIRS 104593-CRWMS M&O 1999, p. 3-32).

Caliente/Chalk Mountain Route. From Caliente to Crystal Springs, this heavy-haul truck route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Rachel the route crosses Hancock Summit and Tikaboo Valley at elevations ranging from about 1,300 to 1,700 meters (4,300 to 5,600 feet). From Rachel to Yucca Mountain the route passes through Sand Spring and Emigrant Valleys, and Yucca Flat, Frenchman Flat, and Jackass Flats, at elevations from 1,700 to

1,900 meters (5,600 to 6,200 feet). Along the entire route, the predominant land cover types are salt desert scrub (37 percent), blackbrush (16 percent), sagebrush (11 percent), and creosote-bursage (10 percent).

Two resident threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente/Chalk Mountain heavy-haul truck route. The Hiko White River springfish (*Crenichthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (DIRS 103262-FWS 1998, p. 16). The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). The part of the route from the northern end of Frenchman Flat to Yucca Mountain is within the range of the desert tortoise (DIRS 101915-Rautenstrauch, Brown, and Goodwin 1994, all). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative abundance of tortoises in this area is low (DIRS 101914-Rautenstrauch and O’Farrell 1998, pp. 407 to 411).

Three species classified as sensitive by the Bureau of Land Management occur within 100 meters (about 330 feet) of this route. The Pahranagat speckled dace occurs in Crystal Springs, Ripley’s springparsley occurs in a number of locations in Yucca Flat on the Nevada Test Site, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of bats classified as sensitive by the Bureau of Land Management might occur along the route and the southern end of the route is within the range of the chuckwalla.

This route crosses six areas designated as game habitat (DIRS 101504-BLM 1979, pp. 2-27 to 2-36; DIRS 101523-BLM 1994, Maps 9, 10, 12, and 13). Meadow Valley Wash is designated important habitat for Gambel’s quail and waterfowl. The route crosses mule deer habitat in four areas: west of Caliente, near Pahroc Summit Pass, in the Pahranagat Range, and in the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range.

Three springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be wetlands or other waters of the United States under Section 404 of the Clean Water Act, including Meadow Valley Wash, an unnamed spring near U.S. 93 west of Caliente, and Crystal Springs and its outflow. No formal wetlands delineation has been conducted along this route. This route also crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

Caliente/Las Vegas Route. From Caliente to Crystal Springs, this candidate route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Las Vegas, the route parallels the White River through Pahranagat Valley, and then through Coyote Springs, Hidden, Dry Lake, Las Vegas, Mercury, and Rock Valleys, and crosses Jackass Flats to Yucca Mountain. Elevations along the section from Crystal Springs to Yucca Mountain range from 610 to 1,200 meters (2,000 to 3,900 feet). Along the route the predominant land cover types are creosote-bursage (62 percent) and Mojave mixed scrub (16 percent).

Four resident threatened or endangered species might occur within 100 meters (about 330 feet) of the Caliente/Las Vegas heavy-haul truck route. The section of the route from about Alamo to Yucca Mountain is within the range of the threatened desert tortoise (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). An approximately 100-kilometer (60-mile) section of U.S. 93 from Maynard Lake south to a point approximately 6 kilometers (4 miles) north of I-15 is critical habitat for the desert tortoise (50 CFR 17.95). The relative abundance of desert tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O’Farrell 1998, pp. 407 to 411). The White River springfish (*Crenichthys baileyi baileyi*, Federally endangered and Nevada protected) has been found in Ash Springs, less than 100 meters from U.S. 93 in northern Pahranagat Valley (DIRS 103262-FWS 1998, pp. 12 to 14). The route crosses the outflow of Ash Springs, which is designated critical habitat for the White River springfish (50 CFR 17.95). The Pahranagat roundtail chub (*Gila robusta jordani*, Federally endangered and Nevada protected) occurs in Ash Springs, the outflow, and throughout Pahranagat Creek, but now is restricted to an approximately 3.5-kilometer (2.2-mile) length of Pahranagat Creek and approximately 2.5 kilometers (1.6 mile) of irrigation ditch in the area (DIRS 103262-FWS 1998, pp. 11 to 12). Southwestern willow flycatchers might occur in dense riparian vegetation near U.S. 93 in Pahranagat Valley.

Nine other species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route. The Pahranagat speckled dace occurs in Ash Springs. The Pahranagat pebblesnail (*Fluminicola merriami*), Pahranagat naucorid (*Pelocoris shoshone shoshone*), and the grated tryonia (*Tryonia clathrata*) occur in Ash Springs, and the Pahranagat Valley montane vole (*Microtus montanus fucosus*) has been observed near the route in Pahranagat National Wildlife Refuge. In addition, pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs along U.S. 93 north of I-15, Ripley's springparsley and Parish's scorpionweed (*Phacelia parishii*) occur adjacent to Jackass Flats Road in eastern Rock Valley, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of other bats classified as sensitive by the Bureau of Land Management occur along the route and most of the route south from Pahranagat Valley is within the range of the chuckwalla and gila monster (*Heloderma suspectus*).

Seven springs, streams, or lakes less than 0.4 kilometer (0.25 mile) from the route might be classified as wetlands under Section 404 of the Clean Water Act, including Meadow Valley Wash, Ash Springs and its outflow, unnamed springs on U.S. 93 west of Caliente and near Maynard Lake, Upper and Lower Pahranagat lakes and their associated marshes, and Maynard Lake. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route crosses eight areas designated as game habitat (DIRS 101504-BLM 1979, pp. 2-26 to 2-35; DIRS 103079-BLM 1998, Maps 3-7 to 3-9). Meadow Valley Wash and much of Pahranagat Valley are designated as habitat for Gambel's quail and waterfowl, and areas along U.S. 93 north of I-15 are designated as quail habitat. U.S. 93 crosses mule deer habitat west of Caliente and around Maynard Lake, two bighorn sheep migration routes, and crucial bighorn sheep habitat north of the U.S. 93 and I-15 junction.

Sloan/Jean Station and Route

The area that DOE is considering for the Sloan/Jean intermodal transfer station is in Ivanpah Valley. DOE is considering three sites in this valley: southwest of Sloan [3.3 square kilometers (810 acres)], northeast of Jean [3.1 square kilometers (760 acres)], and east of Jean [1 square kilometer (260 acres)]. These sites are at an elevation of about 910 meters (3,000 feet) and have vegetation typical of the Mojave Desert. The predominant land cover type is creosote-bursage (97 percent). Elevations along the associated Sloan/Jean heavy-haul truck route range from about 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along the route include creosote-bursage (78 percent), Mojave mixed scrub (12 percent), and urban development (9 percent).

The three sites that DOE is considering for the Sloan/Jean intermodal transfer station are in the range of the threatened desert tortoise. The abundance of tortoises generally is moderate to high in Ivanpah Valley in relation to other areas in Nevada (DIRS 101840-Karl 1980, pp. 75 to 87; DIRS 101521-BLM 1992, Map 3-13). This area is not critical habitat for desert tortoises (50 CFR 17.95).

One species classified by the Bureau of Land Management as sensitive, and by the State of Nevada as protected, occurs in the candidate Sloan/Jean station sites. The pinto beardtongue (*Penstemon bicolor* ssp. *roseus)* has been observed on the site southwest of Sloan and on the site east of Jean. The only game habitat near these areas is bighorn sheep winter range immediately west of the Sloan site (DIRS 103079-BLM 1998, Maps 2-1, 3-7, 3-8, and 3-9). There are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of these sites (DIRS 104593-CRWMS M&O 1999, p. 3-36).

The only resident threatened or endangered species along the Sloan/Jean heavy-haul truck route is the desert tortoise. The entire route is within the range of the desert tortoise (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). The abundance of tortoises along the first part of the route in Ivanpah Valley is moderate to high in relation to other areas in Nevada (DIRS 101521-BLM 1992, Map 3-13). The abundance of tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low to very low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Four species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route. The pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs in the Las Vegas Valley. Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road in eastern Rock Valley on the Nevada Test Site, and the fringed myotis has been observed near the Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitats (DIRS 103079-BLM 1998, Maps 3-7 to 3-9) and there are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile).

Apex/Dry Lake Station and Route

The area that DOE is considering for the Apex/Dry Lake intermodal transfer station is northeast of Las Vegas in Dry Lake Valley. The Department is considering three sites in this area, two to the west of I-15 [0.18 and 3.5 square kilometers (45 and 880 acres)] and one east of the Interstate [0.96 square kilometer (240 acres)] . The elevation of these sites is about 610 meters (2,000 feet). This area is in the Mojave Desert and the predominant land cover type is creosote-bursage (100 percent). The associated route starts at the station area and crosses Las Vegas, Mercury, and Rock Valleys and Jackass Flats to Yucca Mountain at elevations ranging from 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along this route are creosote-bursage (77 percent) and Mojave mixed scrub (16 percent).

The only resident threatened or endangered species along the Apex/Dry lake heavy-haul truck route is the desert tortoise. The entire route passes through desert tortoise habitat (DIRS 103160-Bury and Germano 1994, pp. 57 to 72), and the relative abundance of tortoises along this route through the Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Three species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route. Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road on the Nevada Test Site in eastern Rock Valley, and the fringed myotis has been observed near Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitat (DIRS 103079-BLM 1998, Maps 3-7 to 3-9). There are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of the intermodal transfer station area or the route.

3.2.2.2.5 *Cultural Resources*

The description of environmental conditions in this section focuses on archaeological and historic resources associated with the candidate intermodal transfer station areas and the associated heavy-haul truck routes. In addition, this section discusses Native American interests in relation to several of the heavy-haul truck routes. Unless otherwise noted, the *Environmental Baseline File for Archaeological Resources* (DIRS 104997-CRWMS M&O 1999, all) and *Additional Baseline Cultural Resources Data for the Nevada Transportation Scenario* (DIRS 155826-Nickens and Hartwell 2001, all) are the bases for the information in this section.

Archaeological and Historic Resources. Archaeological data from the candidate intermodal transfer station sites are very limited. Based on a records search at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, four, seven, and two archaeological sites have been recorded at or near the Caliente, Sloan/Jean, and Apex/Dry Lake sites, respectively. These sites have not been evaluated with regard to their potential eligibility for listing in the *National Register of Historic Places*. The I-15 frontage road that runs through the northern location for the Apex/Dry Lake intermodal transfer station is an unrecorded segment of the former Arrowhead Trail Highway, the first automobile highway through southeastern Nevada. Also in this location are the remains of an unrecorded motel and gas station that were associated with the early highway.

Based on recent work by the cultural resources staff at the Harry Reid Center of the University of Las Vegas, Nevada, railroad construction camps could occur in the Apex/Dry Lake or Sloan/Jean intermodal transfer station locations. Seven of these early 20th-century camps were recently excavated in the vicinity of Apex, along with another construction camp associated with a realignment of the Arrowhead Highway in the 1920s. The "Last Spike" site, where the two stretches of the San Pedro, Los Angeles and Salt Lake Railroad were joined in 1905, is within the existing railroad right-of-way adjacent to the middle of the three properties being considered for the Sloan/Jean intermodal transfer station location. Archaeological remains of associated construction camps could occur there as well.

There is some relevant information about the area of the candidate Caliente intermodal transfer locations, which have been extensively disturbed through their current use. Various cultural groups have occupied the Caliente/Meadow Valley Wash area for at least the past 11,000 years (DIRS 103260-Fowler et al. 1973, all; DIRS 102217-D'Azevedo 1986, all). Previously recorded prehistoric archaeological resources in the region include scattered lithic artifacts, rock shelters, temporary camps, and rock art (DIRS 102201-Kautz and Oothoudt 1992, all). Historic archaeological resources in the region typically consist of remains of late nineteenth- and early twentieth-century activities such as mining and ranching.

The Nevada Department of Transportation has completed archaeological field surveys for each of the rights-of-way for the candidate heavy-haul truck routes (Table 3-58). Only the proposed segment of the Caliente/Chalk Mountain route that extends from Highway 375 across Nellis Air Force Range and the Nevada Test Site has not been surveyed. An archival search of a 0.2-kilometer (0.1-mile)-wide corridor along this route identified five archaeological sites, two of which are not eligible for inclusion on the *National Register of Historic Places*; the other three have not been evaluated.

A number of historic properties occur along the proposed heavy-haul truck routes that have been listed on either the *Nevada State Register of Historic Places* or the *National Register of Historic Places*. These historic properties are shown in Table 3-59.

Table 3-58. Number of archaeological sites along 0.2-kilometer (0.1-mile)-wide corridors containing the candidate heavy-haul truck routes.

Site	Eligible	Likely not eligible	Unevaluated	Total
Caliente Route				
Historic	4	13	4	21
Prehistoric	5	57	75	137
Historic/prehistoric	1	2	2	5
Unknown	0	3	12	15
Total	***10***	***75***	***93***	***178***
Caliente/Chalk Mountain Route				
Historic	3	3	2	8
Prehistoric	2	10	6	18
Historic/prehistoric	0	1	0	1
Unknown	0	3	1	4
Total	***5***	***17***	***9***	***31***
Caliente/Las Vegas Route				
Historic	3	6	21	30
Prehistoric	4	25	51	80
Historic/prehistoric	0	1	4	5
Unknown	0	3	10	13
Total	***7***	***35***	***86***	***128***
Sloan/Jean Route				
Historic	5	4	19	28
Prehistoric	1	3	23	27
Historic/prehistoric	0	0	1	1
Unknown	0	0	3	3
Total	***6***	***7***	***46***	***59***
Apex/Dry LakeRoute				
Historic	2	3	15	20
Prehistoric	2	16	11	29
Historic/prehistoric	0	0	1	1
Unknown	0	0	1	1
Total	***4***	***19***	***28***	***51***

Table 3-59. Listed cultural resource properties close to proposed heavy-haul truck routes.[a]

Property	Heavy-haul route	Status[b]
Tonopah Multiple Resource Area	Caliente	NRHP
Goldfield Hotel	Caliente	NSRHP
Goldfield Historic District	Caliente	NRHP
Union Pacific Depot, Caliente	Caliente	NRHP
Smith (Scott) Hotel, Caliente	Caliente	NSRHP
Sedan Crater, Area 10, Nevada Test Site	Caliente/Chalk Mountain	NRHP
Black Canyon Petroglyphs	Caliente/Las Vegas	NRHP

a. Source: DIRS 155826-Nickens and Hartwell (2001, Table 6, pp. 17 to 19).
b. NRHP = *National Register of Historic Places*; NSRHP = Nevada State Register of Historic Places.

Native American Interests. Section 3.2.2.1.5 discusses general Native American concerns about transportation routes. The discussion that follows identifies Native American tribes and lands that could be affected by heavy-haul truck routes. Also discussed are resources (crossed by or near heavy-haul truck routes) identified as having significance for Native Americans.

The Moapa Paiute Indian Tribe is a Federally recognized tribe of about 290 Southern Paiute people. The tribe's reservation near the town of Moapa on I-15 and the Union Pacific Railroad's mainline contains homes and business enterprises. The reservation is about 6 kilometers (4 miles) east of the Caliente/ Las Vegas heavy-haul truck route and about 5 kilometers (3 miles) north of the Apex/Dry Lake station site (DIRS 102043-AIWS 1998, Chapter 4).

The Las Vegas Paiute Tribe is a Federally recognized tribe of about 100 people living on two separate tribal parcels in southern Nevada (DIRS 102043-AIWS 1998, Chapter 4). One parcel near downtown Las Vegas consists of 73,000 square meters (18 acres) of land with about 20 homes, tribal administrative offices, and various tribal business enterprises. This parcel is about 11 kilometers (7 miles) from an overlapping portion of the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul truck routes (northern Las Vegas beltway for the Las Vegas and Apex/Dry Lake routes, and western Las Vegas beltway for the Sloan/Jean route). The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16.2 square kilometers (4,000 acres) with over 10 homes and various business enterprises. An overlapping portion of the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul truck routes goes through a 1.6-kilometer (1-mile) corner of this parcel.

A land transfer of Bureau of Land Management land at Scottys Junction, Nevada, to the Timbisha Shoshone, a Federally recognized tribe of about 280 people located at Death Valley, California, includes 2.4 kilometers (1.5 miles) of frontage along the south side of U.S. 95 along the Caliente heavy-haul truck route. The Timbisha Shoshone plan to use this land for single-family residences and small-scale economic development (DIRS 154121-DOI 2000, Volume I, p. 19).

Although intensive studies are not yet complete, earlier projects involving Native American fieldwork indicate both the presence of and potential for important resources to occur along the candidate heavy-haul truck routes. Ethnographic fieldwork for the Intermountain Power Project in the early 1980s and, more recently, for the proposed intermodal transportation of low-level radioactive waste to the Nevada Test Site has identified the following areas as having significance for Native Americans:

- The Pahranagut Valley contains several places of importance: Maynard Lake area; Lower Pahranagut Storied Rocks; Upper Pahranagut-Black Canyon (Caliente/Las Vegas route)
- Crystal Springs, near the junction of Highways 93 and 318 (Caliente and Caliente/Las Vegas routes)
- Arrow Canyon Valley along U.S. 93 (Caliente/Las Vegas route)
- Caliente downtown area (hot springs and caves) (Caliente route)
- Caliente painted and pecked Storied Rocks (Caliente intermodal transfer station site and heavy-haul truck route)
- Oak Springs Summit area, along U.S. 93 (Caliente and Caliente/Las Vegas routes)
- Six Mile Flat-Pahroc Summit area, along U.S. 93 (Caliente and Caliente/Las Vegas routes)
- Twin Springs, Twin Springs Slough, and Echo Lakes area, along Highway 375 (Caliente route)
- Warm Springs, at the junction of Highways 375 and 6 (Caliente route)

In addition to the areas listed above, many sacred and culturally important Native American places and resources exist on Nellis Air Force Range and the Nevada Test Site, through which the proposed Caliente/ Chalk Mountain heavy-haul truck route passes.

3.2.2.2.6 *Socioeconomics*

The candidate heavy-haul intermodal transfer station sites and routes would not appreciably affect counties other than those in which the facilities were located. Section 3.1.7 contains socioeconomic background information on the three counties (Clark, Lincoln, and Nye) most involved in the heavy-haul truck routes. The Caliente heavy-haul truck route is the only route involving a county outside the region of influence; it passes through Esmeralda County in addition to Lincoln and Nye Counties. Section 3.2.2.1.6 contains socioeconomic information for Esmeralda County.

3.2.2.2.7 *Noise and Vibration*

Most of the proposed routes pass through unpopulated desert with background noise levels of 22 to 38 dBA. All routes pass through small rural communities (see Chapter 6, Figures 6-22 through 6-26). Noise levels in rural communities usually range from 40 to 55 dBA (Table 3-32). Traffic noise along highways generally ranges from 5 to 15 dBA above natural background levels (DIRS 101821-EPA 1974, p. D.5). Roadside noise levels are highly dependent on the volume of traffic, the road surface, composition of the traffic (trucks, automobiles, motorcycles, etc.), and vehicle speed. Measurements taken 90 meters (300 feet) from the centerline of U.S. 95 just outside the Nevada Test Site ranged from 45 to 55 dBA (DIRS 101531-Brown-Buntin 1997, pp. 8 and 9). Less traveled rural highways would have lower 1-hour noise levels, possibly as low as 33 dBA at 90 meters (300 feet) from the centerline. Communities potentially affected by the candidate intermodal transfer stations and associated heavy-haul truck routes were identified by examining the proposed route of each corridor and estimating if construction or heavy-haul vehicle noise could affect area communities. Occasional noise from passing military aircraft occurs near and in the Nellis Air Force Range.

Caliente Station

DOE is considering two parcels of land in Meadow Valley Wash several miles south of Caliente for the intermodal transfer station. A water treatment facility (consisting of drain fields and a pond) adjacent to the larger parcel could contribute to background noise levels. There is a small ranch about 500 meters (1,600 feet) from the larger parcel. The other parcel of land is more remote and has no buildings. Estimated noise levels range from 22 to 45 dBA depending on traffic volume (based on Table 3-32).

Caliente Route. The Caliente heavy-haul truck route goes from Caliente to the Yucca Mountain site, passing through or near the Towns of Caliente, Crystal Springs, Rachel, Tonopah, Goldfield, Beatty, and Amargosa Valley. Estimated noise levels in these communities range from 40 to 55 dBA (based on Table 3-32). This longest route travels on existing highways through predominantly Bureau of Land Management land.

Caliente/Chalk Mountain Route. The Caliente/Chalk Mountain heavy-haul truck route would use existing paved roads to a point in western Lincoln County where it would turn south through the Nellis Air Force Range and the Nevada Test Site. Caliente, Crystal Springs, and Rachel are the only towns through which the heavy-haul truck route would pass. Estimated noise levels in these communities would range from 40 to 55 dBA (based on Table 3-32).

Caliente/Las Vegas Route. The Caliente/Las Vegas heavy-haul truck route follows U.S. 93 from Caliente to I-15, then into Las Vegas primarily on Bureau of Land Management land. The section of the route on the planned Northern Beltway to U.S. 95 would have the highest noise levels, biased toward the 55-dBA level and higher during high traffic volume. Traffic noise levels along U.S. 95 would range from 45 to 55 dBA (DIRS 101531-Brown-Buntin 1997, pp. 8 and 9). Estimated noise levels in Caliente, Crystal Springs, Ash Springs, Alamo, Indian Springs, and Mercury range from 40 to 55 dBA (based on Table 3-32).

Sloan/Jean Station
DOE is considering three parcels of land in the Sloan/Jean area. Some residences, a quarry, and a concrete plant are next to the northernmost site. The eastern parcel is along I-15 adjacent to several commercial enterprises. The third parcel is in the community of Jean and is close to two large casinos. Estimated noise levels in these areas, which are greater than levels encountered in unpopulated desert areas, range from 40 to 55 dBA (based on Table 3-32).

Sloan/Jean Route. The Sloan/Jean heavy-haul truck route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site, and would pass through a number of small towns and the western and northern portions of the Las Vegas Valley. Existing noise levels in the Las Vegas Valley probably range from 52 to 74 dBA; estimated noise levels in Indian Springs, Cactus Springs, and Mercury range from 40 to 55 dBA (based on Table 3-32).

Apex/Dry Lake Station
The candidate location for the Apex/Dry Lake intermodal transfer station is in an unpopulated part of Dry Lake Valley. Existing noise levels are probably somewhat higher than typical levels for a desert environment because of vehicles that travel along I-15 in this area. Depending on local meteorological conditions, noise from the Apex industrial site and passing trains would add to the existing acoustic environment at this site. The northern boundary of one possible location for an intermodal transfer station in the Apex/Dry Lake area is about 3 kilometers (2 miles) south of the Moapa Indian Reservation. There is one manufactured home adjacent to the Dry Lake site.

Apex/Dry Lake Route. The Apex/Dry Lake heavy-haul truck route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site. It would pass through a number of small communities and the north end of the Las Vegas Valley. Existing noise levels in Indian Springs, Cactus Springs, and Mercury probably range from 40 to 55 dBA (Table 3-32). Estimated noise levels in the Las Vegas Valley range from 52 to 74 dBA (based on Table 3-32).

Vibration. The proposed locations of intermodal transfer stations are along existing rail lines. Railroad traffic generates some ground vibration in the vicinity of the line. Depending on the proximity to roads, automobile and truck traffic can create a low level of ground vibration. For the most part, the background vibration levels associated with vehicle traffic are not perceptible to humans, but humans residing close to railroad tracks can perceive some level of ground vibration from trains. Background ground vibration levels are around 52 VdB (root-mean-square velocity) (DIRS 155547-HMMH 1995, p. 7-5) and higher (about 65 VdB) near existing highways and rail lines.

3.2.2.2.8 *Aesthetics*

This section describes the existing aesthetic qualities associated with each of the intermodal transfer station sites and associated heavy-haul truck routes. Section 3.1.10 provides additional description of Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (DIRS 105002-CRWMS M&O 1999, all).

Caliente Station
The proposed location for the Caliente facility is southeast of Caliente, on the western edge of Meadow Valley Wash. This area is in the Caliente Bureau of Land Management resource area and is classified Class III (Figure 3-32). As discussed in Section 3.2.2.2.1, the Caliente intermodal transfer station site is in an area currently used as a wastewater treatment facility and for hay production. The proposed locations are near Kershaw-Ryan State Park (Class II). The entrance to the park is just south of the intermodal transfer station site around a slight bend of topography. The entrance to the park fronts State Route 317 and a Union Pacific mainline.

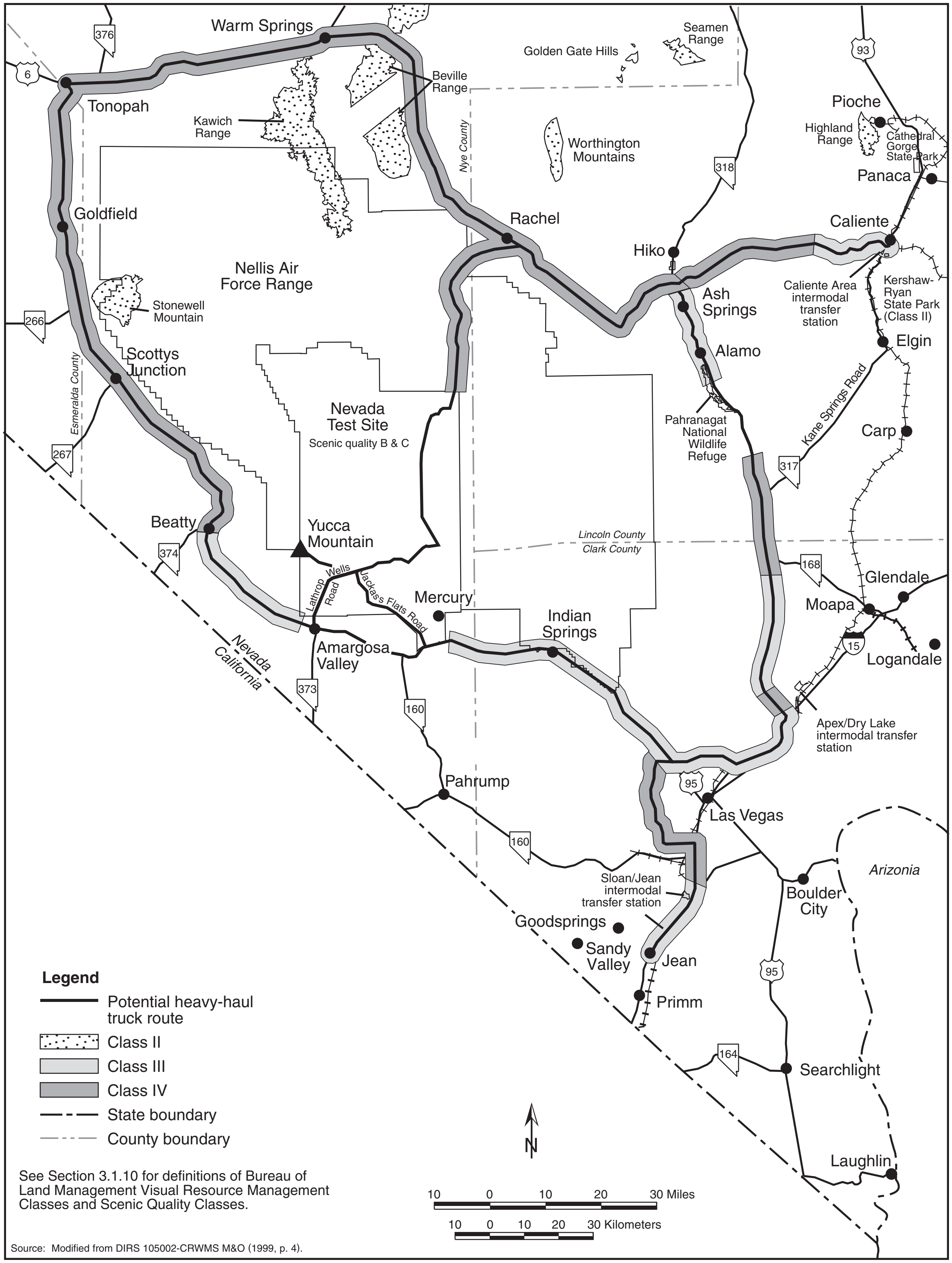

Figure 3-32. Visual Resource Management classes along the potential routes for heavy-haul trucks.

Caliente Route. Section 3.2.2.2.4 describes the environmental setting along the Caliente route. The route passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. From Caliente to the south end of the Burnt Springs Range the route passes through Class III land, and then through Class IV land to Rachel. From Rachel to Tonopah the route crosses Class III land except portions of the Reveille and Kawich Ranges near Warm Springs, which are Class II areas. From Tonopah to Beatty, the route crosses Class IV land, then Class III land from Beatty to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or Class C (Figure 3-32).

Caliente/Chalk Mountain Route. Section 3.2.2.2.4 describes the environmental setting along the route. The route passes through the Caliente and Schell Bureau of Land Management resource areas. From Caliente to the south end of Burnt Springs Range, the route passes through Class III land. From the Burnt Springs Range west through Crystal Springs to Rachel, the route passes through Class IV land. The route from Rachel south crosses Class III and IV land to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-32).

Caliente/Las Vegas Route. Section 3.2.2.2.4 describes the environmental setting along the Caliente/ Las Vegas route. The route passes through the Caliente, Schell, and Las Vegas Bureau of Land Management resource areas. From Caliente to Crystal Springs the route crosses Class III and Class IV land. From Crystal Springs south to the Pahranagat National Wildlife Refuge, the route crosses Class III land. The refuge is rated Class II. The route from the south end of the refuge to I-15 crosses Class III and IV land.

The remainder of the route along I-15, the Northern Beltway, and U.S. 95 passes through Class III land. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-32).

Sloan/Jean Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Sloan/Jean intermodal transfer station and associated route. The potential location for the Sloan/Jean intermodal transfer station has three parcels located some distance apart, two near Jean and one near Sloan. All portions of these parcels are in the Las Vegas Bureau of Land Management resource area adjacent to existing roads and rail lines and are designated as Class III lands. From Jean to Sloan the route travels through Class III lands. From Sloan along the Las Vegas Beltway to U.S. 95 is designated as Class IV lands. The portion of the route to the Nevada Test Site is through Class III lands. The remainder of the route on the Nevada Test Site is classified as scenic quality Class B and C (Figure 3-32).

Apex/Dry Lake Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Apex/Dry Lake intermodal transfer station and route. Most of the land in the potential intermodal transfer areas is classified as Class IV lands. At present, the intermodal transfer station parcels are used for recreation, based on observed trails and two-track roads crossing the parcels, and are located near areas already affected by man as discussed in Section 3.2.2.2.1. A small portion of the southern section of land is designated as Class III lands. The entire route passes through Class III lands from the Apex/Dry Lake siding (and the location of the intermodal transfer station) to the Nevada Test Site boundary. On the Nevada Test Site the route to the repository passes through lands with a scenic quality designated as Class B and C (Figure 3-32).

3.2.2.2.9 *Utilities, Energy, and Materials*

The implementation of the heavy-haul approach for transporting spent nuclear fuel and high-level waste to the repository would involve the construction and operation of an intermodal transfer station and

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upgrades of existing highways. The scope of the utilities, energy, and materials analysis includes consumption of electric power, fossil fuel, and construction materials such as concrete and steel to support these activities. The sites studied for the intermodal transfer station (Caliente, Sloan/Jean, and Apex/Dry Lake) are in areas with at least some light industrial activity or other activity that requires electric power. The sites would, therefore, have access to light industrial levels of electric power. The sites under consideration would also have access to the regional supply capability to provide fossil fuel and construction materials. Heavy-haul truck route upgrades would also use the southern Nevada regional supply system to provide materials for highway upgrades.

3.2.2.2.10 *Environmental Justice*

The candidate location for the Caliente intermodal transfer station is in Lincoln County and the associated heavy-haul truck routes go through Lincoln, Nye, and Esmeralda Counties for the Caliente route; Lincoln and Nye Counties for the Caliente/Chalk Mountain route; and Lincoln, Clark, and Nye Counties for the Caliente/Las Vegas route. Section 3.1.13 discusses minority and low-income populations in Clark, Lincoln, and Nye Counties and includes Figures 3-27 and 3-28, which show locations of minority and low-income communities, respectively, in Nevada. Figures 3-29 and 3-30 provide similar information at a higher resolution for the Las Vegas metropolitan area in Clark County. Section 3.2.2.1.10 discusses minority and low-income populations in Esmeralda County.

The candidate locations for both the Sloan/Jean and Apex/Dry Lake intermodal transfer stations are in Clark County; the associated heavy-haul truck routes both go through Clark and Nye Counties. Section 3.1.13 discusses minority and low-income populations in Clark and Nye Counties.

Some detail on the affected environment for environmental justice that was presented in the Draft EIS for heavy-haul truck routes and intermodal transfer station sites has been deleted because of a change in the nature and level of available information presented. As described in Section 3.1.13, baseline environmental justice data consists of minority populations at the block level based on 2000 Census data (newly available since the Draft EIS) and low-income populations at the block group level based on 1990 Census data. These represent the most up-to-date data in both categories at the time of this document's preparation. Because of the differences in the level of data between the two categories, a combined, parallel discussion is no longer appropriate. The baseline presentation of information now relies on the Section 3.1.13 figures referenced above to identify locations of minority and low-income communities in proximity to the candidate heavy-haul truck routes and intermodal transfer station sites.

3.2.2.2.11 *Existing Traffic on Candidate Routes for Heavy-Haul Trucks*

The description of the affected transportation environment characterizes routes in terms of traffic volume and roadway capability (DIRS 103225-DOE 1998, pp. 3-1 to 3-14). The potential for congestion and other problems on a roadway is expressed in terms of levels of service. The level of service scale ranges from A to F, as follows:

A Indicates free-flow conditions.

B Indicates free-flow, but the presence of other vehicles begins to be noticeable. Average travel speeds are somewhat lower than level of service A.

C Indicates a range in which the influence of traffic density on flow becomes marked. The ability to maneuver in the traffic stream and to select an operating speed is clearly affected by the presence of other vehicles.

D Indicates conditions in which speed and the ability to maneuver are severely restricted due to traffic congestion.

E Indicates full capacity; a disruption, no matter how minor, causes backups to form.

F Indicates breakdown of flow or stop-and-go traffic.

Each level is defined by a range of volume-to-capacity ratios. Level of service A, B, or C is considered good operating conditions in which minor or tolerable delays of service are experienced by motorists. Level of service D represents below average conditions. Level of service E corresponds to the maximum capacity of the roadway. Level of service F indicates a heavily congested or overburdened capacity. Roads outside the Las Vegas metropolitan area are generally level of service A or B; roads inside the Las Vegas metropolitan area are generally level of service E or F. Table 3-60 lists current levels of service on potential heavy-haul truck routes (excluding the planned Las Vegas Beltway).

Table 3-60. Existing levels of service along candidate routes for heavy-haul trucks.[a]

Route segment	Level of service
Caliente	
U.S. 93 to U.S. 6/U.S. 95 interchange	A
U.S. 95/U.S. 6 to Tonopah city limit	C
U.S. 95 (to Mercury, Nevada)	B
Caliente/Chalk Mountain	
Caliente to Rachel	A
Cost of route on U.S. Government Facility	N/A
Caliente/Las Vegas	
U.S. 93 (between I-15 and Caliente)	A
I-15 (to Craig interchange)	A
I-15 (in Las Vegas)	E or F[b]
U.S. 95 (in Las Vegas)	E or F[b]
U.S. 95 (Las Vegas to Mercury)	B
Sloan/Jean	
I-15 (to and in Las Vegas)	C, F[b]
U.S. 95 (in Las Vegas)	C, F[b]
U.S. 95 (Las Vegas to Mercury)	B
Apex/Dry Lake	
I-15 (to Craig interchange	A
I-15 (in Las Vegas)	E and F[b]
U.S. 95 (in Las Vegas)	E and F[b]
U.S. 95 (Las Vegas to Mercury)	B

a. Source: DIRS 103225-DOE (1998, pp. 3-1 to 3-14).
b. Does not consider the Las Vegas Beltway.

3.3 Affected Environment at Commercial and DOE Sites

In response to public comments, DOE has revised Section 3.3 to provide more information on the methodology the Department used to determine baseline conditions at the 72 commercial and 5 DOE sites evaluated under the No-Action analysis. The revisions include added information on the individual site environmental factors (Section 3.3.1) and augmented information on regional environmental factors (Section 3.3.2). In providing this new information, DOE changed the section numbers for the information that appeared in the Draft EIS.

The No-Action Alternative analyzes the impacts of not constructing and operating a monitored geologic repository at Yucca Mountain. It assumes that the spent nuclear fuel and high-level radioactive waste would remain at commercial and DOE sites throughout the United States. This section describes baseline environmental factors at commercial and DOE sites including land use requirements, radiological effluents, worker and offsite populations, and occupational and public radiation doses. These factors provide a basis for comparison of impacts with the Proposed Action and the No-Action Alternative.

In addition to the site environmental factors, this section also includes regional environmental factors for five regions of the United States, including climate, groundwater, waterways, and potentially affected populations. These regional parameters provide the baseline information necessary for estimating potential impacts resulting from the No-Action Alternative Scenario 2 described in Chapter 7 of the EIS.

3.3.1 SITE ENVIRONMENTAL FACTORS

3.3.1.1 COMMERCIAL SITES

At present, there are 103 operating commercial nuclear powerplants at 69 sites in 31 of the contiguous United States. In addition, three sites (Trojan in Oregon, and Humboldt Bay and Rancho Seco in California) have reactors in various stages of decommissioning. The locations of the 72 commercial nuclear powerplants evaluated in this EIS are shown in Figure 3-33. Approximately half of these sites contain two or three nuclear units. There are no commercial nuclear powerplants in Alaska or Hawaii.

3.3.1.1.1 *Land Use and Ownership*

Typically, nuclear powerplant sites and the surrounding areas are flat-to-rolling countryside in wooded or agricultural areas. More than half of the sites have 80-kilometer (50-mile) population densities of fewer than 200 persons per square mile, and more than 80 percent have 80-kilometer densities of fewer than 500 persons per square mile (DIRS 101899-NRC 1996, Section 2.2.1, p. 2-2). The most notable exception is the Indian Point Station, which is within 80 kilometers of New York City, which has a population density of more than 2,000 persons per square mile.

Site areas range from 0.34 square kilometer (84 acres) for the San Onofre Nuclear Generating Station in California to 120 square kilometers (30,000 acres) for the McGuire Nuclear Station in North Carolina. More than half of the plant sites encompass 2 to 8 square kilometers (500 to 2,000 acres). Larger land use areas are usually associated with plant cooling systems that include reservoirs, artificial lakes, and buffer zones. Typically, 0.2 to 0.4 square kilometer (50 to 100 acres) might actually be disturbed during plant construction. Other land commitments can amount to many tens of square kilometers for transmission line rights-of-way and cooling lakes (if used).

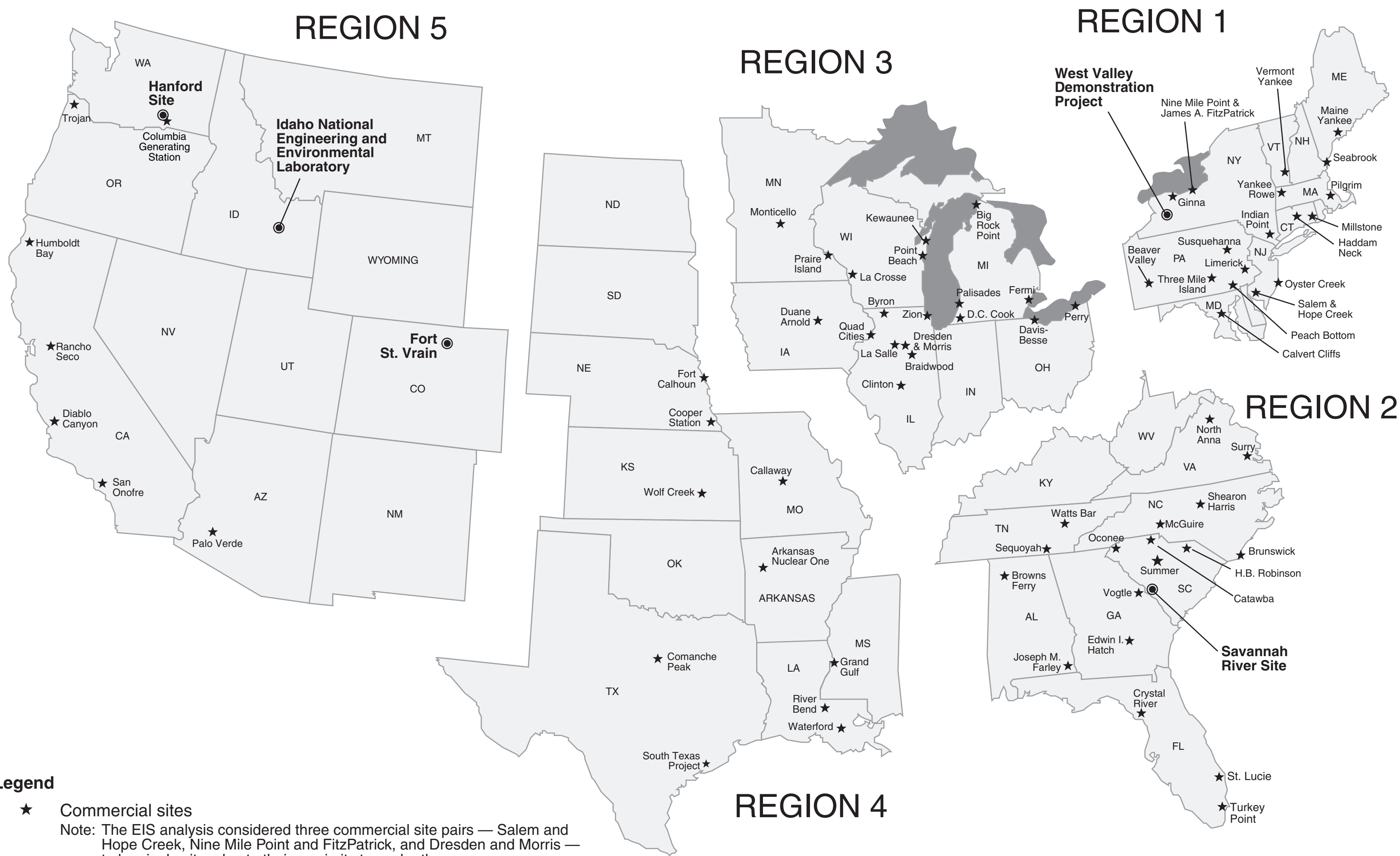
In general, these sites are owned and maintained by the investor owned utilities (sites operated by the Tennessee Valley Authority are Federally owned) that operate the associated power plants and control egress to the sites to protect the health and safety of the public.

3.3.1.1.2 *Socioeconomic Environment*

Although the size of the workforce varies considerably among sites, the average permanent staff size at a nuclear powerplant ranges from 800 to 2,400 people, depending on the number of operating units at the site (DIRS 101899-NRC 1996, Section 2.3.8.1, p. 2-26). In rural or low-population communities, the number of permanent jobs can represent a substantial portion of the local workforce.

In addition to the permanent workforce, many temporary workers are required for tasks that occur during refueling and maintenance outages. Between 200 and 900 additional workers can be employed during these outages to perform the normal maintenance work. Although these temporary workers are in the community for only a short time (usually 1 to 2 months a year), they can have a substantial effect on the area (DIRS 101899-NRC 1996, Section 2.3.8.1, p. 2-27).

In addition to direct employment, plant subcontractors and service industries in the area provide hundreds of indirect jobs. In rural communities, industries that provide this number of jobs at relatively high wages are major contributors to the local economy. In addition to the beneficial effect of these jobs, plant purchasing and worker spending can generate considerable income for local businesses (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).



Legend

★ Commercial sites
Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites
Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Note: None of the facilities evaluated are located in Alaska or Hawaii.

Symbols do not reflect precise locations.

Source: Modified from DIRS 101911-Poe (1998, p. 2).

Figure 3-33. Commerical and DOE sites in each No-Action Alternative analysis region.

A nuclear powerplant represents an investment of several billion dollars. Such an asset on the tax rolls is extraordinary for rural communities and can constitute the major source of local revenues for small or remote taxing jurisdictions. This revenue often enables higher quality and more extensive public services with lower tax rates to the citizens (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).

For these reasons, nuclear powerplants can have a significant positive effect on the local community environment. These effects are stable and long-term. Because these effects generally enhance the economic structure of the local community, nuclear powerplants become a major positive contributor to the local area (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).

3.3.1.1.3 *Radioactive Effluents*

During normal operations, nuclear powerplants release small amounts of radioactive materials to the environment through atmospheric and aquatic pathways. These radioactive materials, released under controlled conditions, include fission and activation products. Releases to the atmosphere consist primarily of the noble gases and some of the more volatile materials like tritium, isotopes of iodine, and cesium. Releases to aquatic pathways consist primarily of nonvolatile fission and activation products such as isotopes of cesium and cobalt. After appropriate holdup and processing, these materials are monitored carefully before and during releases to determine whether the licensed release limits can be met (for example, 10 CFR Part 20, Appendix I to 10 CFR Part 50, 10 CFR 50.36a, and 40 CFR Part 190).

In 1993 (the last year for which information is readily available), boiling-water and pressurized-water reactors released about 31,000 and 28,000 curies, respectively, of fission and activation gases to the atmosphere (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 1 and 2, pp. 6-12). Thus, the estimated average atmospheric release per boiling-water reactor and pressurized-water reactor was 760 and 380 curies per year, respectively.

In addition, boiling-water reactors and pressurized-water reactors released 0.75 and 0.30 curies, respectively, of iodine-131 and particulates to the atmosphere (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 3 and 4, pp. 12-17). This resulted in boiling-water reactor and pressurized-water reactor average unit releases of 0.018 and 0.0041 curies, respectively.

Liquid releases of tritium in 1993 for boiling-water reactors and pressurized-water reactors totaled about 530 and 36,000 curies, respectively (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 5 and 6, pp. 18-24), and about 11 and 35 curies, respectively (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 7 and 8, pp. 24-29), of mixed fission and activation products.

3.3.1.1.4 *Occupational and Public Health and Safety*

Occupational Radiation Exposures

Nuclear plant workers who conduct activities involving radioactively contaminated systems or who work in radiation areas can be exposed to radiation. Most of the occupational radiation dose to such workers results from external radiation rather than internal exposure to inhaled or ingested radioactive materials. Pursuant to reporting requirements of 10 CFR 20.2206, the Nuclear Regulatory Commission received annual reports from 104 licensees that operated commercial nuclear power reactors in 1999. These reports consisted of radiation exposure records for each monitored individual. The reports are analyzed for trends and summarized in annual reports (DIRS 155099-Karagiannis and Hagemeyer 2000, all) in terms of collective dose and the distribution of dose among the monitored individuals.

In 1999, the total collective occupational dose for all operating commercial reactors was almost 14,000 person-rem or an average per licensee of 131 person-rem (DIRS 155099-Karagiannis and Hagemeyer 2000, Table 3.2, p. 3-5). This total collective dose was received by about 114,000 monitored workers for an average annual individual dose of 120 millirem, which is about 40 percent of the average background radiation dose for the United States, as listed in Table 3-30. However, of the 114,000 monitored workers, about half (55,000 workers) had no measurable dose. Of the approximately 59,000 workers who had a measurable dose, the estimated annual average radiation exposure was 230 millirem, or about 77 percent of the national average background radiation dose of 300 millirem.

In addition to nuclear powerplant licensees, in 1999 the Nuclear Regulatory Commission received annual radiation exposure reports from two Independent Spent Nuclear Storage Facility operators. The reported annual collective dose for these two licensees was 5 person-rem received by 86 monitored individuals, for an annual average of 60 millirem. Of the monitored individuals, only 33 received measurable radiation doses for an annual average of 150 millirem. These doses represent 20 and 50 percent, respectively, of the national average background radiation dose of 300 millirem.

Public Radiation Exposures

Releases of radioactive materials from nuclear power reactors result in radiation doses to humans that are small in relation to doses from natural background radiation. Persons can be exposed to radiation from nuclear power reactors through atmospheric and aquatic pathways. When an individual is exposed through one of these pathways, the dose is determined by the amount of the radioactive material a person could inhale or ingest. The amount of radioactive material inhaled or ingested is determined by the exposure time and the radioactive material concentrations in the various environmental media. The resulting dose is determined by radionuclide-specific dose conversion factors, which are based on physical decay and metabolic properties of the radioactive material in the body.

The major exposure pathways include the following:

- Inhalation of contaminated air
- Drinking milk or eating meat from animals that graze on open pasture on which radioactive contamination might fall
- Eating vegetables grown near the site
- Drinking water or eating fish caught near the point of discharge of liquid effluents

Other less important exposure pathways include external irradiation from surface deposition; consumption of animals that drink irrigation water that might contain liquid effluents; consumption of crops grown near the site using irrigation water that might contain liquid effluents; shoreline, boating, and swimming activities; and direct radiation to offsite individuals.

In 1992 (the last year for which information is readily available), the estimated total population doses for populations living within 80 kilometers (50 miles) of operating nuclear power reactors were 32 person-rem by waterborne pathways and 15 person-rem by airborne pathways, for a total of 47 person-rem (DIRS 155092-Aaberg and Baker 1996, Table 1.4, p. 1.9). However, estimated population dose commitments for the waterborne and airborne pathways varied widely among the sites. The total dose commitments from both pathways for individual sites varied from a high of 3.7 person-rem to a low of 0.0015 person-rem. The arithmetic mean for the total dose from liquid pathways (0.44 person-rem) and airborne pathways (0.21 person-rem) was 0.66 person-rem (DIRS 155092-Aaberg and Baker 1996, p. 1.11). The estimated average annual dose to the offsite individual living within 80 kilometers was 0.0003 millirem, which is a very small fraction of the average annual dose from natural background radiation of 300 millirem in the United States.

In addition to average population doses, maximally exposed individual doses were estimated for commercial nuclear power sites for comparison with the 10 CFR Part 50, Appendix I, numerical guides for design objectives [10 CFR 50.34a(a)], which require nuclear powerplant licensees to design and operate their facilities in a manner that maintains offsite doses from liquid and atmospheric effluents *as low as reasonably achievable*. For the more than 70 sites reporting in 1992, the arithmetic mean of the maximum annual dose from atmospheric pathways for an offsite individual living at the nearest residence was about 0.012 millirem from releases of noble gases and 0.27 millirem to any organ (thyroid, lung, etc.) from releases of iodines and particulate material. For the liquid pathways, the arithmetic mean of the *maximally exposed individuals* for all reporting sites was about 0.12 millirem (DIRS 155092-Aaberg and Baker 1996, Table 1.4, p. 1.9).

For the waterborne pathways, tritium, zinc-65, and isotopes of cesium accounted for 31, 14, and 43 percent of the total dose, respectively. For the airborne pathways, tritium and isotopes of xenon accounted for 44 and 46 percent of the dose, respectively (DIRS 155092-Aaberg and Baker 1996, Table 1.8, pp. 1.17 through 1.22).

3.3.1.2 DOE SITES

This EIS focuses on the five DOE sites at which spent nuclear fuel and high-level radioactive waste currently exists or where existing Records of Decision have authorized placement of these materials (see Chapter 7, Section 7.2 for details). The five sites are the Hanford Site, the Idaho National Engineering and Environmental Laboratory, Fort St. Vrain (spent nuclear fuel only), the West Valley Demonstration Project (high-level radioactive waste only), and the Savannah River Site (Figure 3-33).

3.3.1.2.1 *Land Use and Ownership*

Of the five DOE sites that manage spent nuclear fuel and high-level radioactive waste, three (Hanford Site, Idaho National Engineering and Environmental Laboratory, Savannah River Site) are on large tracts of Federally owned land ranging from 2,300 square kilometers (890 square miles) for Idaho National Engineering and Environmental Laboratory to 800 square kilometers (310 square miles) for the Savannah River Site. On these three sites, most of the land is undeveloped or forest management areas. These undeveloped areas serve as buffer zones between the operating areas and the public. Access to these sites is controlled for national security purposes to prevent ingress by unauthorized personnel.

The Fort St. Vrain Independent Spent Nuclear Fuel Installation and West Valley Demonstration Project are on much smaller tracts of land, 3.8 acres and 220 acres, respectively, which are mostly developed but are surrounded by low-population-density lands used mostly for agricultural and residential purposes.

3.3.1.2.2 *Socioeconomic Environment*

Because of their large employment base, the Hanford Site, Idaho National Engineering and Environmental Laboratory, West Valley Demonstration Project, and Savannah River Site represent a substantial portion of their respective local workforces. For example, in December 1997 the Hanford Site employed almost 11,000 DOE and contractor personnel, which represented 13 percent of the total employment in the area (DIRS 156931-DOE 2000, p. 4-101). Similarly, in 1998 Idaho National Engineering and Environmental Laboratory and Savannah River Site employed 8,100 and 14,000 workers, respectively, which represented about 7 percent of their local area workforces (DIRS 156914-DOE 2000, all). In 1993, the West Valley Demonstration Project employed more than 1,000 DOE and contract workers and was the largest local employer; these workers represented almost 4 percent of the local workforce (DIRS 101729-DOE 1996, p. 4-58).

In 1995, approximately 230 persons worked at the Fort St. Vrain site. Of these, approximately 16 full-time-equivalent personnel worked on the Independent Spent Fuel Storage Facility (DIRS 103213-DOE 1996, Appendix E, Section 3, pp. 3-53 and 54). Based on the 1980 census, the population within an 8 kilometer (5-mile) radius of the site was 3,148, with 1,662 residing in the Town of Platteville. The projected population for 2012 (through the 20-year license) for this area will be 4,526, with 3,040 residing in Platteville. However, even with this relatively small local workforce, the 16 workers and the DOE site would have minimal impact.

In addition to base employment, DOE sites contribute to the local economic conditions through the creation of indirect employment and through the purchase of goods and services from local firms.

3.3.1.2.3 *Radioactive Effluents*

As a result of ongoing process and *remediation* activities, most DOE sites routinely release quantities of radioactive materials to the atmosphere and surface waters that eventually enter the surrounding environment. These effluents are carefully monitored at their points of discharge to ensure that releases remain within limits specified by DOE Orders and applicable state and Federal statutes and regulations.

Radioactive materials released from DOE sites consist of fission and activation products (such as tritium, cesium, strontium, iodine, and krypton), transuranics (such as plutonium and americium), and source material (such as uranium). Atmospheric releases consist primarily of tritium and noble gases (such as krypton and argon), and liquid releases consist primarily of tritium with much smaller quantities of fission products and transuranics. The Idaho National Engineering and Environmental Laboratory typically does not release radioactive liquid effluents off the site. Rather, liquid effluents are sent to two plastic-lined evaporation ponds (DIRS 156914-DOE 2000, Section 7.1, p. 7-3) that prevent percolation of contaminated water into the ground and eventual release to the *accessible environment*. In addition, the Hanford Site 200-Area facilities discharge radioactive liquid effluents to the 616-A-Crib (also known as the State-Approved Land Disposal Site) rather than directly to the Columbia River (DIRS 156931-DOE 2000, Section 3.1.3, p. 3.6). The Fort St. Vrain site does not have atmospheric or liquid effluents (DIRS 155101-DOE 1998, Section 2.3.4.1, p. 2-25 and Section 2.4.2, p. 2-35) because the spent nuclear fuel is stored in sealed canisters and is not typically handled or processed.

In 1999, the four DOE sites with radioactive effluents discussed in this section released about 92,000 *curies* of fission and activation products to the atmosphere (DIRS 156914-DOE 2000, Table 7-1, p. 7-4; DIRS 156931-DOE 2000, Table 3.1.1, p. 3.6; DIRS 155094-Arnett and Mamatey 2000, Table 4, p. 13; DIRS 154284-WVNS 2000, Tables D-2 through D-11, pp. D-4 through D-12). Most of these releases occurred at the Savannah River Site, which released about 89,000 curies. The Savannah River Site atmospheric releases consisted almost entirely of tritium (about 52,000 curies) and noble gases (about 37,000 curies). In addition, the four sites released 0.0025 curie of transuranics and 0.048 curie of source material to the atmosphere.

In 1999, the DOE sites released about 6,400 curies of fission and activation products in liquid effluents (DIRS 156914-DOE 2000, Table 7-2, p. 7-5; DIRS 156931-DOE 2000, Tables 3.1.3 and 3.1.4, p. 3.7; DIRS 155094-Arnett and Mamatey 2000, Table 6, p. 22; and DIRS 154284-WVNS 2000, Table C-1, p. c-3). More than 99 percent of these releases consisted of tritium, and most (about 6,300 curies) occurred at the Savannah River Site.

3.3.1.2.4 *Occupational and Public Health and Safety*

Occupational Radiation Exposures

In 1999, DOE reported a total workforce (including contractors) of approximately 130,000 individuals (DIRS 155091-DOE 1999, Exhibit 3-1, p. 3-2). Of these individuals, about 113,000 were monitored for potential radiation exposure. Only about 17,000 received measurable doses. The collective dose is the sum of the doses received by all individuals who had measurable doses, and is reported in person-rem. The collective dose is an indicator of the overall radiation exposure at DOE facilities and includes doses to all DOE employees, contractors, and visitors. DOE monitors the collective dose as one measure of the overall performance of radiation protection programs to keep individual and collective exposures as low as reasonably achievable.

For the five sites discussed in this section, DOE reported a total collective dose of about 380 person-rem for 1999 (DIRS 155091-DOE 1999, Exhibit 3-17, p. 3-17). This dose was received by almost 6,000 individuals with measurable doses, for an average annual dose of about 60 millirem per person. This dose represents 20 percent of the national average background dose of 300 millirem. The Fort St. Vrain site reported no measurable doses for 1999.

Public Radiation Exposures

In a manner similar to that described in Section 3.3.1.1.4 for commercial sites, DOE estimates collective and individual doses for populations living within 80 kilometers (50 miles) of their operations facilities. In 1999, for the five DOE sites discussed in this section, the total estimated offsite population dose was about 7.1 person-rem. This dose was received by a total 80-kilometer population of about 2.5 million people for an average dose of about 0.003 millirem per person, which is a very small fraction of the average annual dose from natural background radiation of 300 millirem in the United States (DIRS 156914-DOE 2000, Table 8-3, p. 8-9; DIRS 156931-DOE 2000, Table 5.0.2, p. 5.9; DIRS 155090-Arnett and Mamatey 2000, Table 7-2, p. 118, p. 121; DIRS 155094-Arnett and Mamatey 2000, Table 32, p. 125; DIRS 154284-WVNS 2000, Table 4-2, p. 4-7). Most of this collective dose (6.6 person-rem) was received by persons living around and downstream of the Savannah River Site and is attributed to atmospheric and liquid releases of tritium (3.5 person-rem) (DIRS 155094-Arnett and Mamatey 2000, Table 41, p. 135 and Table 48, p. 144). Fort St. Vrain reported that radioactive effluents and direct radiation from the site in 1999 did not contribute to any increase in offsite doses (DIRS 155093-Newkirk and Hall 2000, p. 7).

In addition to average population doses, DOE estimated doses for the hypothetical maximally exposed offsite individual. For the four sites with reported offsite doses, the maximally exposed offsite individual received a maximum dose of 0.28 millirem (DIRS 155100-DOE 1999, p. 8-4; DIRS 155097-DOE 1999, p. 5.4; DIRS 155090-Arnett and Mamatey 2000, p. 122; DIRS 154284-WVNS 2000, Table 4-2, p. 4-7), primarily from atmospheric and liquid releases of tritium (0.10 millirem) and liquid releases of cesium-137 (0.13 millirem) (DIRS 155094-Arnett and Mamatey 2000, Table 42, p. 136, and Table 45, p. 141).

3.3.2 REGIONAL ENVIRONMENTAL FACTORS

For analytic purposes, DOE divided the country into five regions (see Figure 3-33). This section describes the affected environment for each region that reflects the average or mean conditions of the sites in the region. The affected environment includes spent nuclear fuel and high-level radioactive waste inventories, climatic parameters, groundwater flowrates, downstream surface-water users, and downstream surface-water flowrates. In all cases, DOE used data consisting of average or mean conditions from actual sites to develop hypothetical sites.

To develop the hypothetical sites, DOE divided the generator sites among the five regions (Figure 3-33). Climate varies considerably across the United States. Radionuclide release rates would depend primarily on the interaction of climate and materials. DOE analyzed release rates for a hypothetical site in each region that was a mathematical representation of the actual sites in that region. The development process for the hypothetical site used weighted values for material inventories, climate, and groundwater flow information from each actual site to ensure that the results of the analyses of the hypothetical site were comparable to the results for each actual site, if analyzed independently. Similarly, the process constructed downstream populations of water users and river flow for the hypothetical sites from population and river flow data for actual sites, so they reflect the populations downstream of actual storage facilities and the actual amount of water those populations use.

3.3.2.1 REGIONAL INVENTORIES OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

Table 3-61 lists the Proposed Action quantities of commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste in each of the five regions. The information in the table is a projection of quantities and forms that would exist at a point in the future, not as they currently exist. For example, high-level radioactive waste is listed in the table as having gone through a vitrification process with subsequent packaging in canisters, as if ready for disposal in a repository.

Table 3-61. Proposed Action quantities of spent nuclear fuel (metric tons of heavy metal) and canisters of high-level radioactive waste in each geographic region.[a,b]

Region	Commercial spent nuclear fuel[c,d]	DOE spent nuclear fuel[e]	High-level radioactive waste[f,g]
1	16,800	0	300
2	18,900	30	6,000
3	14,700	0	0
4	7,200	0	0
5	5,400	2,300	2,000
Totals	63,000	2,300	8,300

a. Source: Appendix A.
b. Totals might differ from sums due to rounding.
c. Analyzed as stored on surface, as shown on Chapter 2, Figures 2-32, 2-33, and 2-34.
d. Includes plutonium in mixed-oxide spent nuclear fuel, which is assumed to behave like other commercial spent nuclear fuel.
e. A representative or surrogate fuel that consisted primarily of N-reactor fuel.
f. Includes plutonium in can-in-canister.
g. Historically, a canister of high-level radioactive waste has been assumed to be equivalent to about 0.5 MTHM (see Appendix A, Section A.2.3.1).

3.3.2.2 CLIMATIC FACTORS AND MATERIAL

DOE assumed that a single hypothetical site in each region would store all the spent nuclear fuel and high-level radioactive waste in each region. Such a site does not exist, but DOE used it for this analysis. To ensure that the calculated results of the regional analyses reflected the appropriate inventory, facility and material degradation, and radionuclide transport, DOE developed the spent nuclear fuel and high-level radioactive waste inventories, engineered barriers, and environmental parameters for the hypothetical site from data from the actual sites in that region. Weighting criteria accounted for the different amounts and types of spent nuclear fuel and high-level radioactive waste at each site, so the results of the analyses of the hypothetical site were representative of the sum of the results if DOE had modeled each actual site independently. If there are no storage areas in a particular part of a region, DOE did not analyze the environmental parameters of that part (for example, there are no storage facilities in the Upper Peninsula of Michigan, so the analysis for Region 3 did not include environmental parameters from cities in the Upper Peninsula). In addition, if the storage area would not affect drinking water (for example, groundwater near the Calvert Cliffs Nuclear Generating Plant outcrops to the Chesapeake Bay), the regional hypothetical storage facility did not include their fuel inventories.

The following climate parameters are important to material degradation times and rates of release:

- Precipitation rate (amount of precipitation per year)
- Rain days (percent of days with measurable precipitation)

- Wet days (percent of year that included rain days and days when the relative humidity was greater than 85 percent)
- Temperature
- Precipitation chemistry (pH, chloride anions, and sulfate anions)

Table 3-62 lists the regional values for each parameter. Appendix K contains more information on the selection and analysis of these parameters.

Table 3-62. Regional environmental parameters.

Region	Precipitation rate (centimeters per year)[a]	Percent rain days (per year)	Percent wet days (per year)	pH	Precipitation chemistry: Chloride anions (weight percent)	Precipitation chemistry: Sulfate anions (weight percent)	Average temperature (ºC)[b]
1	110	30	31	4.4	6.9×10^{-5}	1.5×10^{-4}	11
2	130	29	54	4.7	3.9×10^{-5}	9.0×10^{-5}	17
3	80	33	42	4.7	1.6×10^{-5}	2.4×10^{-4}	10
4	110	31	49	4.6	3.5×10^{-5}	1.1×10^{-4}	17
5	30	24	24	5.3	2.1×10^{-5}	2.5×10^{-5}	13

a. To convert centimeters to inches, multiply by 0.3937.
b. To convert degrees Centigrade to degrees Fahrenheit, add 17.78 and then multiply by 1.8.

3.3.2.3 GROUNDWATER PARAMETERS

Most of the radioactivity and metals from degraded material would seep into the groundwater and flow with it to surface outcrops to rivers or streams. Therefore, the analysis had to account for the groundwater characteristics at each site, including the time it takes the water to move through the unsaturated zone and the aquifer. The analysis assumed that the storage facilities would be 490 meters (1,600 feet) up the groundwater gradient from the hypothetical reactor and used this assumption to calculate the time it would take contaminants to reach surface water. Table 3-63 lists the ranges of groundwater flow times in each region. Appendix K contains more information on the sources of groundwater data.

Table 3-63. Ranges of flow time (years) for groundwater and contaminants in the unsaturated and saturated zones in each region.

Region	Contaminant K_d[a] (milliliters per gram)	Unsaturated zone: Water flow time	Unsaturated zone: Contaminant flow time	Saturated zone: Groundwater flow time	Saturated zone: Contaminant flow time	Total contaminant flow time
1	0[b] - 100	0.7 - 4.4	0.4 - 2,100	0.3 - 56	10 - 5,000	10 - 6,000
2	10 - 250	0.6 - 10	35 - 5,000	3.3 - 250	11 - 310,000	460 - 310,000
3	10 - 250	0.5 - 14	32 - 1,500	1.3 - 410	9 - 44,000	65 - 45,000
4	10 - 100	0.2 - 7.1	110 - 2,300	3.9 - 960	300 - 520,000	460 - 520,000
5	0 - 10	0.9 - 73	14 - 4,700	1.7 - 170	0 - 25,000	200 - 26,000

a. K_d = equilibrium adsorption coefficient.
b. The K_d would be 0 if there was no soil at the site.

3.3.2.4 AFFECTED WATERWAYS

Most of the estimated population dose for the No-Action Alternative would be a result of drinking contaminated surface water. The first step in determining the population dose was to identify the waterways that receive groundwater from beneath existing storage facilities (Figure 3-34) and the number of public drinking water systems that draw water from the potentially contaminated waterways

Symbols do not reflect precise locations.

Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Note: The Great Lakes and the St. Lawrence Seaway are considered major waterways.

Source: Modified from DIRS 101911-Poe (1998, p. 13).

Figure 3-34. Major waterways near commercial and DOE sites.

(Table 3-64). DOE calculated the river flow past each population center (Section 3.3.2.5) along each river, and used this number in the calculation to determine dose to the population.

Table 3-64. Public drinking water systems and the populations that use them in the five regions.[a]

Region	Drinking water systems	Population
1	85	10,000,000
2	150	5,600,000
3	150	12,000,000
4	95	600,000
5	6	2,800,000
Totals	***486***	***31,000,000***

a. Sources: Based on current information and the 1990 census.

3.3.2.5 AFFECTED POPULATIONS

After identifying the affected waterways, DOE identified the populations that get their drinking water from those waterways. The total population using the river was expressed as number of people per cubic foot per second. If a river system traverses more than one region (for example, the Mississippi drains three regions), weighting criteria accounted for materials received from storage facilities upstream of the region that would flow past several downstream population centers, as necessary. Table 3-64 lists the number of people using the public drinking water systems potentially affected by the degradation of radioactive materials.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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4

Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure

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4. ENVIRONMENTAL CONSEQUENCES OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

This chapter describes short-term environmental consequences that could result from the implementation of the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. *Short-term* refers to the period from the beginning of construction through final repository closure, and includes project phases of construction, operation and monitoring, and closure. For purposes of analysis, the repository would remain open from 115 to 341 years from the beginning of construction to final closure, depending upon the operating mode and operating parameters selected. Chapter 5 discusses the environmental consequences of long-term repository performance—that period out to 10,000 years and beyond after repository closure. Chapter 6 discusses the environmental consequences of transportation, and Chapter 7 discusses the environmental consequences of the No-Action Alternative.

Section 4.1 describes potential environmental impacts from required activities at the repository site to implement the Proposed Action, including continued site investigations (called *performance confirmation*), offsite manufacturing of repository components (for example, disposal containers and drip shields) and shipping casks, and a floodplain assessment. The implementation of the Proposed Action would require performance confirmation in support of a U.S. Nuclear Regulatory Commission licensing process. Section 4.2.1 describes potential environmental impacts of retrieval if such an option became necessary. Section 4.2.2 describes the environmental impacts associated with the receipt of waste prior to the start of emplacement.

The U.S. Department of Energy (DOE) has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the Nuclear Waste Policy Act, as amended (NWPA), in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. This chapter contains information about short-term environmental impacts that would be directly associated with the construction, operation and monitoring, and eventual closure of a repository.

4.1 Short-Term Environmental Impacts of Performance Confirmation, Construction, Operation and Monitoring, and Closure of a Repository

This section describes the short-term environmental impacts associated with the Proposed Action. DOE has described the environmental impacts according to the phases of the Proposed Action—construction, operation and monitoring, and closure—and the activities (some of which overlap) associated with them. The following paragraphs summarize the phases and activities that would occur, and the operating modes evaluated in this environmental impact statement (EIS). Chapter 2 describes these operating modes in detail. Figure 4-1 shows the expected timeline for these phases. In addition, this section describes the impacts from the testing and performance confirmation activities that DOE would perform before the start of repository construction in support of a Nuclear Regulatory Commission licensing process. These activities, which would continue through repository closure, could require surface or subsurface excavations and drill holes, testing, and environmental monitoring. As these activities revealed more scientific data, DOE would expect their level of effort to decrease.

PRECONSTRUCTION TESTING AND PERFORMANCE CONFIRMATION ACTIVITIES

The preconstruction testing and performance confirmation program would continue many of the same types of activities performed during site characterization—tests, experiments, and analyses—for as long

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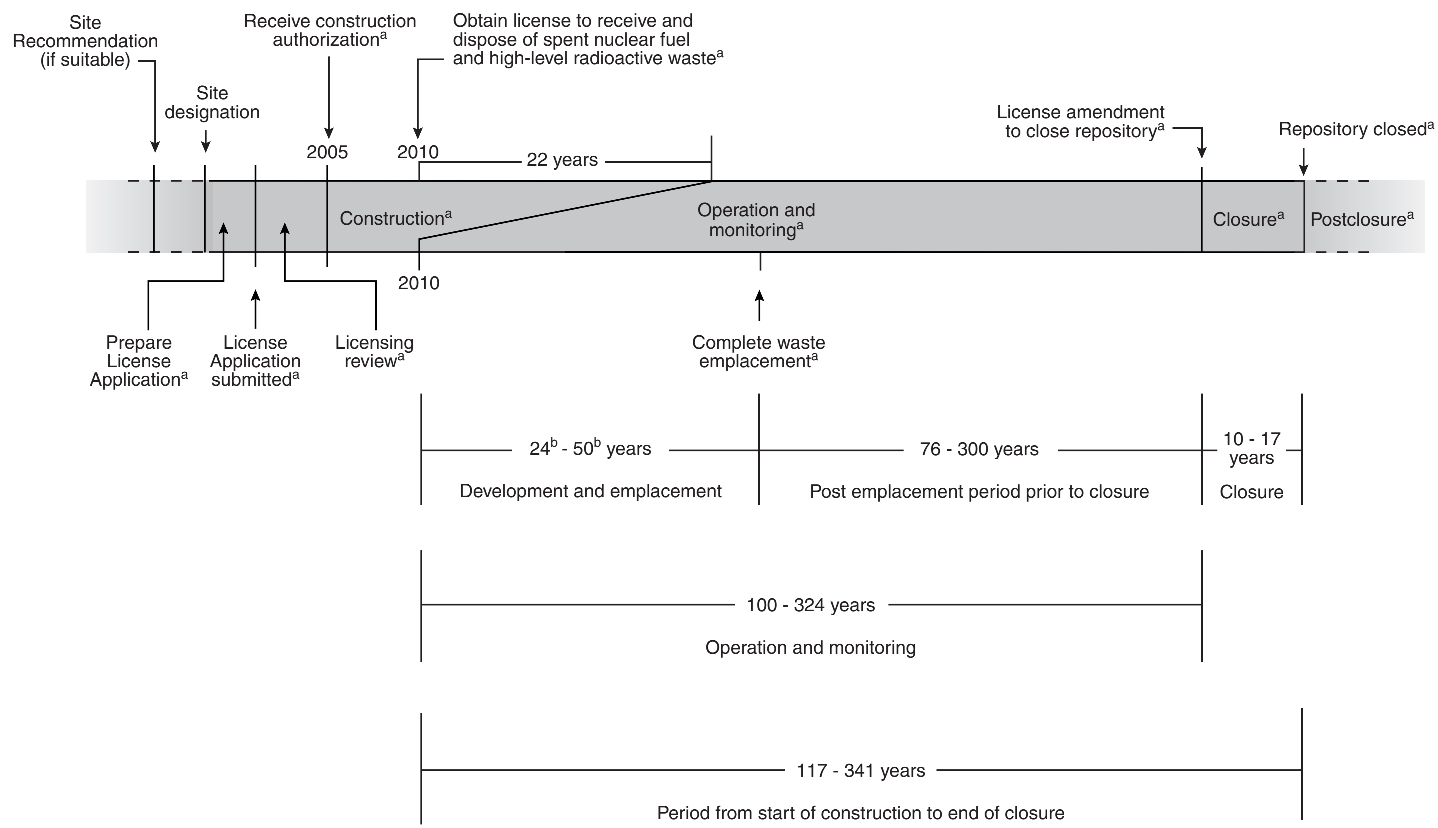

a. If Yucca Mountain is approved.

b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Note: See Table 2-2 for range of emplacement, preclosure ventilation, and closure durations.

Sources: Modified from DIRS 104523-CRWMS M&O (1999, Figure 1.5-1, p.1-3).

Figure 4-1. Monitored geologic repository range of milestones used for analysis.

as required. DOE would continue performance confirmation activities during all the phases of the repository project to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the repository would meet the performance objective for the period after *permanent closure*.

INITIAL CONSTRUCTION PHASE (STARTING IN 2005, LASTING 5 YEARS)

The construction of facilities would begin when and if the Nuclear Regulatory Commission authorized DOE to build the repository. For analysis purposes, this EIS assumed construction would begin in about 2005. Site preparation, including the layout and grading of surface facility locations, would be part of the initial construction activities; DOE would construct new surface facilities or modify facilities built to support site characterization. Most surface facility construction would be completed during this phase, with the exception of the solar facility and aging pads, if built. Initial subsurface construction would excavate access mains, ventilation shafts, and the first emplacement drifts and prepare them for the start of emplacement activities, assumed for analysis purposes to begin in 2010. As mentioned above, performance testing and confirmation activities would be ongoing during this period.

OPERATION AND MONITORING PHASE

The operation and monitoring phase would last 100 to 324 years and would consist of an operations period and a monitoring period. The EIS analyses assumed that repository operations would begin in 2010, assuming DOE received a license from the Nuclear Regulatory Commission to receive and dispose of spent nuclear fuel and high-level radioactive waste. The operations period would include continued development (excavation and preparation for use) of the subsurface repository, receipt and handling of spent nuclear fuel and high-level waste in surface facilities, and emplacement of these materials in the completed portions of the subsurface repository. Development activities would last 22 years for all operating modes, concurrent with handling and emplacement. Handling and emplacement activities would last 24 years for the higher-temperature operating mode and for the lower-temperature operating mode if surface aging was not used. If surface aging was used, the operations period would last 50 years.

Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of waste packages and would continue through the closure phase. After the completion of emplacement, the monitoring period would begin, during which monitoring would be the primary activity. DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of predictions of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary. This period would last from 76 to 300 years. The first 3 years of the monitoring period would include the radioactive decontamination of surface facilities used for handling radioactive materials. Facilities would be decontaminated so there would be no chance for release of contamination when they were in standby mode during the monitoring period, and they would be ready for either demolition during the Closure Phase or for use as part of a retrieval contingency.

Future generations would need to decide whether to continue to maintain the repository in this open monitored condition or to close it. However, the Department expects that a repository could be maintained in an open monitored condition, with appropriate maintenance, for the time periods evaluated in this chapter. For this analysis, the EIS evaluates closure starting 100 years after the start of emplacement for the higher-temperature operating mode, and 149 to 324 years for the lower-temperature operating mode.

As mentioned above, DOE would continue its performance confirmation activities during the development, waste emplacement, and monitoring activities.

CLOSURE PHASE (LASTING 10 TO 17 YEARS)

Repository closure would occur after DOE applied for and received a license amendment from the Nuclear Regulatory Commission. Closure would take 10 years for the higher-temperature operating mode and from 11 to 17 years for the lower-temperature operating mode, depending on the operating parameters that had been employed. The closure of the repository facilities would include the following activities:

- Removing and salvaging valuable equipment and materials
- Backfilling the main drifts, access ramps, ventilation shafts, and connecting openings and sealing underground-to-surface openings
- Constructing monuments to mark the area
- Decommissioning and demolishing surface facilities
- Restoring the surface to its approximate condition before repository construction
- Continuing performance confirmation activities as necessary

REPOSITORY OPERATING MODES

As discussed in Chapter 2, the repository design is conceptual and continues to evolve. This evolution will continue throughout the process established by the Nuclear Regulatory Commission for license application and construction authorization. To present the range of short-term environmental impacts that could occur, DOE has selected a range of higher-temperature to lower-temperature operating modes for evaluation in this EIS. The higher-temperature operating mode has an established set of operating parameters (DIRS 153849-DOE 2001, all). The desired characteristics for a lower-temperature operating mode could be reached under a variety of operating parameters, and was evaluated using a range of parameter values affecting repository size and ventilation characteristics, number and spacing of waste packages, and length of activity periods. Elsewhere in this EIS (Chapter 6 and Appendix J) the potential impacts of specific transportation and fuel packaging options (Appendix F) are examined. Where transportation and spent fuel packaging options may make a difference in repository impact analysis, legal-weight truck transportation option and/or uncanistered spent fuel packaging have been assumed because they typically result in the highest potential impacts. There are a few exceptions to this general rule, for example, where use of canisters for fuel packaging would result in additional waste. These instances are specifically identified where they occur in Chapter 4.

4.1.1 IMPACTS TO LAND USE AND OWNERSHIP

This section describes potential land-use and ownership impacts from the preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. DOE determined that information useful in an evaluation of land-use and ownership impacts should identify the current ownership of the land that repository-related activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts is a land withdrawal area that DOE used for the EIS analysis. Congress would have to define the actual land withdrawal area. The analysis considered impacts from direct disturbances related to repository construction and operation. It also considered impacts from the transfer of lands to DOE control.

4.1.1.1 Impacts to Land Use and Ownership During Preconstruction Testing and Performance Confirmation and from Land Withdrawal

Preconstruction testing and performance confirmation activities would occur primarily on land managed by the Federal Government. As with site characterization, these activities would occur in the land withdrawal area that DOE analyzed in the EIS (see Section 3.1.1). DOE would seek to maintain the current administrative land withdrawal of 20 square kilometers (7.7 square miles), current right-of-way reservations N-47748 [210 square kilometers (81 square miles)] and N-48602 [about 75 square kilometers (29 square miles)], and the existing management agreement between the Yucca Mountain Site Characterization Office and the Nevada Operations Office (as described in Section 3.1.1) until Congress approved a permanent land withdrawal. The Nevada Operations Office operates the Nevada Test Site.

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of the land surrounding the repository site. The Department believes that an area of approximately 600 square kilometers (230 square miles) on Bureau of Land Management, U.S. Air Force, and DOE lands in southern Nevada would be sufficient (see Section 3.1). Of the 600 square kilometers, approximately 210 square kilometers (81 square miles) comprise the right-of-way reservation noted above, with 180 square kilometers (70 square miles) remaining in public lands under the Bureau of Land Management's right-of-way agreement with DOE. As such, these lands are currently available for public use including mineral exploration and recreation. There are several current mining and mineral claims within the parcel that would be affected by withdrawal from public use. Such leases and unpatented mining claims could be withdrawn by the Bureau of Land Management or could be voided by an act of Congress that would withdraw the land for a repository. The current recreational use of the land under the Bureau of Land Management's right-of-way agreement could also be withdrawn by the Bureau or by establishment by Congress of a repository at Yucca Mountain.

Nuclear Regulatory Commission licensing conditions for a repository (10 CFR 60.121) include a requirement that DOE either own or have permanent control of the lands for which it is seeking a repository license. As noted above, portions of the area proposed for the repository are lands controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. Nuclear Regulatory Commission regulations require that repository operations areas and postclosure controlled areas be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise. If Congress approved withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal.

Repository construction, operation and monitoring, and closure activities would require the active use of a maximum of about 6 square kilometers (1,500 acres, 2.3 square miles) composed of small noncontiguous areas within the larger 600-square-kilometer (230-square-mile) land withdrawal area used for purposes of analysis.

Chapter 2 describes activities that DOE would conduct in the Yucca Mountain site active-use area and the land withdrawal area.

The amount of land that DOE would need to support repository activities would vary little among repository operating modes. Most of the surface facilities and disturbed land would be in the South

Portal Development Area and North Portal Operations Area. Repository activities would not conflict with current land uses on adjacent Bureau of Land Management, Air Force, or Nevada Test Site lands.

4.1.1.2 Impacts to Land Use and Ownership from Construction, Operation and Monitoring, and Closure

During the construction and operation and monitoring phases, DOE would disturb or clear land for the repository and surface facility construction. The Department would use this land for surface facilities, performance confirmation activities, and excavated rock storage. DOE does not expect conflicts with uses on surrounding lands because repository operations would occur in a confined, secure area over which DOE would have permanent control. Furthermore, this is public land, much of which has been used for repository site characterization for nearly two decades.

As described in Section 4.1, surface activities associated with closure would include constructing monuments, decommissioning and decontaminating facilities, and restoring the surface to its approximate preconstruction condition. DOE could use material from the excavated rock pile to backfill the repository tunnels (excluding the emplacement drifts), and would contour the excavated material remaining after backfill and subsurface closure activities and cover it with topsoil. During closure, the Department would restore disturbed areas to their approximate condition before repository construction.

Surface disturbance for the higher-temperature operating mode would be 4.3 square kilometers (1,000 acres). Surface disturbance for the lower-temperature operating mode would range from 4.5 square kilometers (1,100 acres) to approximately 6 square kilometers (1,500 acres). The surface disturbance represents a small amount of the 600 square kilometers (150,000 acres) of land withdrawn for the repository. Therefore, there would be small impacts to land use due to the implementation of the Proposed Action.

4.1.2 IMPACTS TO AIR QUALITY

This section describes possible nonradiological and radiological impacts to air quality from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure. Appendix G provides more details on the methods used for air quality analysis.

Sources of nonradiological air pollutants at the proposed repository site would include fugitive dust emissions from land disturbances and excavated rock handling; nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter emissions from fossil fuel consumption; and fugitive dust emissions from concrete batch plant operations. DOE used the Industrial Source Complex computer program to estimate annual and short-term (24-hour or less) nonradiological air quality impacts (DIRS 103242-EPA 1995, all). Nonradiological impacts evaluated include those from four criteria pollutants: nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}). In addition, potential impacts were evaluated for the possibly harmful mineral cristobalite, a form of silica dust that is the causative agent for silicosis and might be a carcinogen. The analysis did not quantitatively address the two other criteria pollutants, lead and ozone (see Appendix G, Section G.1). There would be no sources of airborne lead at the repository, and very small sources of volatile organic carbon compounds, which are ozone precursors. The analysis did make a general comparison to the pending National Ambient Air Quality Standard for particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$), which has yet to be implemented (see Chapter 3, Section 3.1.2.1). DOE used these standards, among other air quality standards shown in Chapter 3, Section 3.1.2.1, in analyzing the nonradiological air quality impacts discussed in this section.

Radiological air quality impacts could occur from releases of radionuclides, primarily naturally occurring radon-222 and its radioactive decay products, from the rock into the subsurface facility and then into the

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ventilation air during all phases of the repository project. Radioactive noble gases, principally krypton-85, would be released from surface facilities during the handling of spent nuclear fuel. DOE used dose factors from DIRS 101882-NCRP (1996, Volume 1, pp. 113 and 125) to estimate doses to *noninvolved workers* (workers who could be exposed to air emissions from repository activities but who would not be directly associated with those activities) and offsite individuals from such releases.

The air quality analysis evaluated nonradiological air quality impacts at the potential locations of maximally exposed members of the public. It estimated radiological air quality impacts as the doses to maximally exposed individuals and populations of the public and to noninvolved workers. The analysis did not consider involved workers because they would be exposed in the workplace, as discussed in Section 4.1.7. Overall, the impacts to regional air quality from performance confirmation, repository construction, operation and monitoring, and closure would be small. Exposures of maximally exposed individuals to airborne pollutants would be a small fraction of applicable regulatory limits. For periods of 1 year or longer, maximally exposed individuals were assumed to be at the southern boundary of the land withdrawal area, the closest location they would be for long periods during repository activities.

4.1.2.1 Impacts to Air Quality from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would generate particulate and gaseous emissions. Particulates would be generated by drilling, blasting, rock removal and storage, batch concrete plant operation, surface grading and leveling, wind erosion, and vehicle travel on paved and unpaved roads. Gaseous air pollutant emissions would consist of carbon monoxide, *nitrogen oxides*, *sulfur oxides*, and hydrocarbons. These pollutants would be produced by diesel- and gasoline-powered construction equipment and motor vehicles and by diesel-powered drilling engines and electric generators.

Air quality measurements at the repository site and in the repository site vicinity (see Section 3.1.2) have shown that site characterization activities similar to those described above have had a very small impact on the concentration levels of PM_{10} and of gaseous pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone). This analysis assumed that site characterization activities are representative of preconstruction testing and performance confirmation activities. As described in Section 3.1.2, pollutant levels have been below applicable National Ambient Air Quality Standards. Based on this experience, DOE does not expect large impacts to air quality from preconstruction testing and performance confirmation activities.

4.1.2.2 Impacts to Air Quality from Construction

This section describes potential radiological and nonradiological air quality impacts during the initial construction of the Yucca Mountain Repository, which for analysis purposes would last 5 years, from 2005 to 2010. Activities during this phase would include subsurface excavation to prepare the repository for initial emplacement operations and construction of surface facilities at the North Portal Operations Area, South Portal Development Area, and ventilation shaft areas and associated access roads.

4.1.2.2.1 *Nonradiological Impacts to Air Quality from Construction*

During the initial construction, repository activities would result in emissions of air pollutants. Subsurface excavation would release dust (particulate matter) from the ventilation exhaust. The excavation of rock would generate dust in the drifts. The dust would be vented from the subsurface through the South Portal. Construction activities on the surface would result in the following air emissions:

- Fugitive dust from the placement and maintenance of excavated rock at a surface storage site

- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from the operation of construction vehicles
- Gaseous criteria pollutants and particulate matter from a diesel-fueled boiler at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Fugitive dust from land-disturbing activities on the surface during construction activities

Table 4-1 lists the maximum estimated impacts to air quality at the boundary of the land withdrawal area used for purposes of analysis in this EIS. As listed in this table, maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small. Criteria pollutant concentrations would be less than 2 percent of the applicable regulatory limits for all operating modes with the exception of PM_{10}. The 24-hour PM_{10} concentrations for the range of operating modes would be about 4 to 6 percent of the regulatory limit. In addition, DOE expects levels of $PM_{2.5}$ to be well below the applicable standard because a large fraction of the particulates for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not have a major effect on concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-1. Maximum construction phase concentrations of criteria pollutants and cristobalite at the land withdrawal area boundary (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.40	0.41 - 0.42	0.41	0.41 - 0.42
Sulfur dioxide	Annual	80	0.10	0.10	0.13	0.13
	24-hour	365	1.3	1.3	0.36	0.36
	3-hour	1,300	8.5	8.6 - 8.7	0.66	0.66 - 0.67
Carbon monoxide	8-hour	10,000	4.2	4.3 - 4.4	0.041	0.042 - 0.043
	1-hour	40,000	29	29 - 30	0.072	0.073 - 0.075
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.69	0.74 - 0.94	1.4	1.5 - 1.9
	24-hour	150 (65)	6.5	7.0 - 8.4	4.3	4.7 - 5.6
Cristobalite	[Annual[d]]	[10[d]]	0.018	0.017 - 0.018	0.18	0.17 - 0.18

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Emissions of nitrogen dioxide, sulfur dioxide, and carbon monoxide would not be greatly different under the higher- and lower-temperature operating modes during the construction phase. Differences do result for PM_{10} releases during the larger land disturbances and maintenance of the larger excavated rock piles of the lower-temperature operating modes. The construction of ventilation shafts and their access roads contributes significantly to the particulate releases. Although well within regulatory limits, particulate release rates would be further reduced by dust suppression measures taken during construction.

Cristobalite is one of several naturally occurring crystalline forms of silica (silicon dioxide) that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for involved workers who could inhale it during subsurface excavation operations (see Section 4.1.7). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of lung tissue. Research has shown an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (DIRS 103243-EPA 1996, p. 1-5). The evaluation of exposure to cristobalite encompassed potential impacts from exposure to other forms of crystalline silica, including quartz and tridymite, that occur at Yucca Mountain. See Appendix F, Section F.1.2, for more information.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). Using the parent rock percentage probably overestimates the airborne cristobalite concentration because studies of both ambient and occupational airborne crystalline silica have shown that most is coarse and not respirable, and that larger particles rapidly deposit on the surface (DIRS 103243-EPA 1996, p. 3-26). Table 4-1 lists estimated cristobalite concentrations at the analyzed land withdrawal area boundary during the construction phase.

There are no regulatory limits for public exposure to cristobalite. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter. For added conservatism, this analysis used an annual concentration of 10 micrograms per cubic meter as the benchmark for comparison. The postulated annual average exposure of the hypothetical maximally exposed member of the public to cristobalite from construction activities would be small, about 0.02 microgram per cubic meter or less for the various operating modes, or less than 0.2 (0.11) percent of the benchmark. DOE would use common dust suppression techniques (water spraying, etc.) to further reduce releases of fugitive dust, and hence cristobalite, from the excavated rock pile.

4.1.2.2.2 *Radiological Impacts to Air Quality from Construction*

No releases of manmade radionuclides would occur during the construction phase because such materials would not be present until the repository began operations. However, the air exhausted from the subsurface would contain naturally occurring radon-222 and its radioactive decay products. (Further references to radon in this discussion include its radioactive decay products.) Radon-222 is a noble gas and decay product of uranium-238 that occurs naturally in the rock. Exposure to radon-222 is ubiquitous (that is, it occurs everywhere). As described in Chapter 3, Section 3.1.8, exposure to naturally occurring radon-222 results in an annual average individual dose in the United States of about 200 millirem. In the subsurface, radon-222 would leave the rock and enter the drifts, a process called radon emanation. Once in the repository drifts the radon and decay products would be exhausted as part of repository ventilation. DOE based potential future releases of radon-222 on modeled estimates of radon flux, concentration, and release in the repository (DIRS 154176-CRWMS M&O 2000, all). These estimates were generated using observed radon concentrations in the Exploratory Studies Facility (DIRS 150246-CRWMS M&O 2000, Attachment X) and considering the repository structure and ventilation characteristics, particularly the ventilation pressure differentials. Total estimated radon releases during the 5-year construction phase would be very similar for the range of repository operating modes. These releases, and the potential doses that resulted from them, would be similar because the size and structure of the excavated repository and the repository ventilation would be similar under each mode during the construction phase. Appendix G, Section G.2, describes the methods, procedures, and basis of analysis.

The dose to the offsite maximally exposed individual, at the southern boundary of the land withdrawal area, would be about 1.7 to 2.0 millirem for the 5-year initial construction phase under the flexible design repository operating modes. The maximum annual dose to the offsite maximally exposed individual would be no more than about 0.53 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3.5 percent of this standard. The offsite population dose would be 33 to 40 person-rem. The maximum annual dose to the maximally exposed noninvolved repository worker would be about 1.9 to 2.3 millirem during the initial construction phase. The analysis assumed that this worker, while at the site, would be in an office about 100 meters (330 feet) from the South Portal. The noninvolved worker population exposed to radon-222 from exhaust ventilation would include all the repository workers on the surface. Workers at the South Portal Development Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. The dose to the noninvolved worker population from the air *pathway* would be less than 0.5 (0.48) person-rem during this phase (see Appendix G, Section G.2).

Table 4-2 lists estimated annual and 5-year construction phase doses from radon-222 for the maximally exposed individuals (both public and noninvolved surface worker) and potentially affected populations from the air pathway. Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-2. Radiation doses to maximally exposed individuals and populations during initial construction phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual	Total	Maximum annual
Dose to public				
Offsite MEI[c] (millirem)	1.7	0.43	1.7 - 2.0	0.43 - 0.53
80-kilometer population[d] (person-rem)	33	8.4	33 - 40	8.4 - 10
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	7.5	2.0	7.5 - 9.0	1.9 - 2.3
Yucca Mountain noninvolved worker population[f] (person-rem)	0.41	0.10	0.41 - 0.48	0.10 - 0.13
Nevada Test Site noninvolved worker population[g] (person-rem)	0.0013	0.00032	0.0013 - 0.0015	0.00032 - 0.00039

a. Numbers are rounded to two significant figures.
b. Annual values are for the maximum year during the construction phase.
c. MEI = maximally exposed individual; public MEI location would be at the southern boundary of the land withdrawal area.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
e. The maximally exposed noninvolved worker location would be in the South Portal Development Area.
f. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.3 Impacts to Air Quality from Operation and Monitoring

This section describes potential nonradiological and radiological air quality impacts from routine operation and monitoring at the Yucca Mountain Repository. For analysis purposes, this phase would begin in 2010 for both repository operating modes; it would last for 100 years for the higher-temperature operating mode and from 149 to 324 years for the lower-temperature operating mode. Activities during this phase would include the continued excavation of subsurface drifts (beginning in 2010 and lasting 22 years), the receipt and packaging (handling) of spent nuclear fuel and high-level radioactive waste at the North Portal surface facilities (beginning in 2010 and lasting 24 years), and the emplacement of disposal containers in the repository (beginning in 2010 and lasting 24 years without aging or 50 years with aging). These activities would take place concurrently. After the emplacement of all spent nuclear fuel, monitoring of the disposal containers and maintenance of repository facilities would last from 76 to 300 years.

4.1.2.3.1 *Nonradiological Impacts to Air Quality from Operation and Monitoring*

DOE evaluated nonradiological air quality impacts from activities beginning at 2010, when handling and continued subsurface development and emplacement activities would occur simultaneously. This phase could last from 100 to 324 years, depending on the operating mode and design. Continued development of the subsurface facilities would last 22 years for all operating modes. Continued subsurface development would result in the release of dust (particulate matter) from the ventilation exhaust (at the South Portal). Activities on the surface would result in the following air emissions during this period:

- Fugitive dust emissions from the excavation, placement, and maintenance of rock at a surface storage pile
- Fugitive dust emissions from continued construction of the aging pads, if used to achieve lower-temperature operations
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide) and particulate matter from vehicle operation during construction and emplacement
- Gaseous criteria pollutants and particulate matter from diesel-fed boilers at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Cristobalite emissions from subsurface excavations and the excavated rock storage pile

The level of emissions would vary among the operating modes. The lower-temperature operating mode would result in larger excavated rock piles on the surface, which in turn would result in larger fugitive dust emissions and necessitate larger vehicle fleets for operation and maintenance.

Table 4-3 lists estimated maximum concentrations at the land withdrawal area boundary for the higher- and lower-temperature operating modes.

As listed in Table 4-3, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be very small. For the range of operating modes, the public maximally exposed individual would be exposed to less than 2 (1.6) percent of the applicable regulatory limits. In addition, levels of $PM_{2.5}$ should be well below the applicable standard because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. The concentrations of $PM_{2.5}$ would not be as affected by these suppression measures because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-3 also lists cristobalite concentrations at the land withdrawal area boundary. As discussed for the initial construction phase (see Section 4.1.2.2.1), the analysis of the continuing construction, operation, and monitoring period assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. There are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The

Table 4-3. Maximum criteria pollutant and cristobalite concentrations at the land withdrawal area boundary during the operation and monitoring phase (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.28	0.28 - 0.31	0.28	0.29 - 0.32
Sulfur dioxide	Annual	80	0.089	0.089 - 0.092	0.11	0.11 - 0.12
	24-hour	365	1.2	1.2	0.33	0.34
	3-hour	1,300	7.8	7.9 - 8.0	0.60	0.61 - 0.62
Carbon monoxide	8-hour	10,000	2.7	2.7 - 3.0	0.026	0.027 - 0.029
	1-hour	40,000	19	19 - 21	0.048	0.049 - 0.052
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.080	0.10 - 0.19	0.16	0.20 - 0.39
	24-hour	150 (65)	0.97	1.3 - 2.3	0.65	0.87 - 1.6
Cristobalite	Annual[d]	10[d]	0.0093	0.009 - 0.017	0.093	0.091 - 0.17

a. All numbers except regulatory limits are rounded to two significant figures.

b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).

c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.

d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

estimated exposures to cristobalite from repository operations would be small, about 0.017 microgram per cubic meter or less for the range of operating modes, or less than 0.2 (0.11) percent of the benchmark.

Concentrations would differ between the construction phase and the emplacement and development activities. The rate of fugitive dust release and the subsequent PM_{10} concentrations would be higher during the construction phase than during emplacement and development activities because of the differing amount of land surface disturbance. Concentrations of cristobalite would be comparable in the construction and operation and monitoring phases. Concentrations of gaseous criteria pollutants would decrease during emplacement and development activities because vehicle emissions would decrease during emplacement and development. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions among the operating modes.

After the completion of emplacement activities, DOE would continue monitoring and maintenance activities lasting 76 to 300 years at the repository until closure. During this period, air pollutant emissions would decrease. Subsurface excavation and handling activities would be complete, resulting in a lower level of emissions. Pollutant concentrations at the land withdrawal area boundary, therefore, would be lower than those listed in Table 4-3.

The flexible design repository operating modes would remove at least 70 percent of the heat generated by the spent nuclear fuel inventory during the preclosure period (DIRS 153849-DOE 2001, p. 2-15). The peak ventilation air temperature for the higher-temperature operating mode would be 58ºC (136ºF) for 1.4-kilowatt-per-meter linear thermal load, occurring 10 years into the preclosure period and decreasing thereafter (DIRS 150941-CRWMS M&O 2000, pp. 4-24 to 4-25). The higher-temperature operating mode has the highest linear thermal load (DIRS 153849-DOE 2001, p. 2-24) and would have the highest exhaust air temperatures. This air temperature would be lower than the exhaust air temperature of many other industrial processes such as powerplants, manufacturing facilities, and incinerators. Impacts from the heat released in ventilation air would be unlikely on either the climate or ecosystems of the area.

4.1.2.3.2 *Radiological Impacts to Air Quality from Operation and Monitoring*

The handling of spent nuclear fuel and continued subsurface ventilation would result in radionuclide releases during the early years of the operation and monitoring phase. Radionuclides would be released during transfer of fuel assemblies from transportation casks to disposal containers. Releases of naturally occurring radon-222 from subsurface ventilation would continue. If surface aging was used, the initial 24 years of operations would be followed by 26 years of emplacing commercial spent nuclear fuel from the aging facility. Aging would result in a 50-year operations period rather than the 24-year period without aging.

After the completion of handling and emplacement operations, DOE would continue monitoring repository facility maintenance activities for 76 to 300 years. During this period, the Department would continue to ventilate the subsurface. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

Operations Period. The main radionuclide released to the atmosphere from the handling of spent nuclear fuel assemblies in the Waste Handling Building would be krypton-85, a radioactive noble gas (DIRS 101893-NRC 1979, p. 4-10). Approximately 2,600 curies would be released annually (DIRS 152010-CRWMS M&O 2000, p. 52). Releases of other noble gas radionuclides would be very small. Estimated annual releases would be about 1.0×10^{-6} curie of krypton-81, 3.3×10^{-5} curie of radon-219, 5.9×10^{-2} curie of radon-220, and 4.6×10^{-6} curie of radon-222 (DIRS 152010-CRWMS M&O 2000, p. 52). Releases of these radionuclides, which are noble gases, would not be affected by facility filtration systems. No releases of particulate or soluble radionuclides would be likely. These radionuclides would be captured in the water of the transfer pool or the Waste Handling Building air filtration system.

A continuing source of dose to members of the public and noninvolved (surface) workers would be releases of naturally occurring radon-222 from the subsurface. Estimated radon emissions during the continuing construction, operation, and monitoring period would be greater than those during the initial construction period because of the larger repository size, with more surface area for radon flux from the repository walls and greater quantities exhausted by ventilation. The effect of waste packages heating the walls of the emplacement drifts, which would slightly increase the radon flux, was also considered (DIRS 154176-CRWMS M&O 2000, p. 10). The estimated differences in radon releases would be a function primarily of the waste package spacing, which would affect the total repository size, and of the duration of the monitoring period. In general, a larger waste package spacing distance would lead to a larger repository, which would result in more radon released per year and a shorter ventilation period. Annual releases, therefore, would be higher but total releases would be lower. Appendix G, Section G.2.3.1, contains more information on estimates of radon release for the range of operating modes. Activation of the air around waste packages would result in the creation of a small quantity of radioactive noble gases. These noble gases would contribute negligibly to the dose from the air pathway (DIRS 139546-CRWMS M&O 2000, all).

Table 4-4 lists estimated annual doses and doses during the handling and emplacement period to the maximally exposed individuals (public and noninvolved worker) and potentially affected populations from radionuclide releases from surface and subsurface facilities. As for the other project phases, naturally occurring radon-222 and its decay products released in subsurface ventilation air would be the major dose contributors from airborne releases. Krypton-85 and the other noble gas radionuclides released from the surface facilities would be a small component of the overall dose, contributing less than 0.01 percent of the dose to the public and typically less than 1 percent of the dose to noninvolved workers for the operations period. The principal exception would be the dose to the noninvolved worker population at the Nevada Test Site, where the krypton-85 contribution to dose would be as high as 3.5 percent of the total dose. Appendix G, Section G.2.3.2, discusses the methods for calculating the doses, and Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-4. Radiation doses for maximally exposed individuals and populations during the operations period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual[c]	Total	Maximum annual[c]
Dose to public				
Offsite MEI[d] (millirem)	12	0.73	17 - 43	1.0 - 1.3
80-kilometer population[e] (person-rem)	230	14	320 - 830	20 - 26
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[f] (millirem)	30	2.0	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker population[g] (person-rem)	1.2	0.081	1.8 - 1.9	0.12 - 0.13
Nevada Test Site noninvolved worker population[h] (person-rem)	0.011	0.00063	0.015 - 0.043	0.00090 - 0.0012

a. Numbers are rounded to two significant figures.
b. Fuel handling activities would last 24 years. Emplacement activities would last 24 years with no aging or 50 years with aging. Continuing subsurface development activities would last 22 years.
c. Maximum annual dose would occur during the last year of development, when the repository had reached its largest and DOE still used the South Portal for exhaust ventilation.
d. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker location would be in the South Portal Development Area.
g. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

The dose to the offsite maximally exposed individual would be 12 to 20 millirem during the 24 years of operations, increasing to 43 millirem for the additional 26 years of operations if DOE used aging. The maximum annual dose to the offsite maximally exposed individual would be about 0.73 to 1.3 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 5 to 9 percent of this standard. The population dose would be 230 to 390 person-rem for 24 years of operations, increasing to 830 person-rem for the additional 26 years of operations with aging. Essentially the entire dose would be from naturally occurring radon-222 released from the subsurface in ventilation air. Releases of radioactive noble gases from surface facilities (Waste Handling and Waste Treatment Buildings) during spent nuclear fuel handling would make very small differences in the dose received. Aging would increase the operations period by 26 years, but also would decrease the monitoring period by 26 years, so the total impact would be unchanged.

The dose to the maximally exposed noninvolved (surface) worker in an office about 100 meters (330 feet) from the South Portal would be about 30 to 42 millirem during the 24 years of handling and emplacement activities, increasing less than 0.2 millirem for the additional 26 years of operations for aging. The increase would be small because DOE would stop using the South Portal for exhaust ventilation at the completion of development, and exhaust from the ventilation shafts would result in much less dose to the maximally exposed worker. The dose to the noninvolved worker population would vary in proportion to (1) the amount of radon-222 released from the subsurface, because radon-222 would dominate the radiation doses, and (2) the number of noninvolved (surface) workers. At the North Portal Operations Area, there would be about 1,300 workers annually (a total of 31,000 to 32,000 worker-years for 24 years of operations). This total would increase to about 50,000 surface worker-years for the 50 years of operations needed for aging. In addition, an estimated 1,500 to 2,100 total subsurface worker-years would be needed on the surface at the South Portal Development Area (see Appendix G, Table G-49). The noninvolved worker population dose would range from 1.2 to 1.8 person-rem over the 24-year emplacement period, increasing slightly to 1.9 person-rem considering the additional 26 years of the operations period needed for aging. Workers at the South Portal Development Area, who would be near the ground-level releases of radon from this portal during development activities, would receive most of the population dose from airborne releases. However, the bulk of worker radiation dose comes not from airborne releases but from more direct occupational exposure. Section 4.1.7 discusses impacts to workers directly involved in handling, emplacement, and continuing development activities.

Monitoring Period. Monitoring would continue and maintenance would begin immediately after the completion of emplacement activities. One of the first activities would be the decontamination of the surface material handling facilities. This activity, which would last 3 years, would require a larger number of noninvolved workers. These workers would be exposed to naturally occurring radon ventilated from the subsurface. Decontamination of the surface facilities would result in no or negligible airborne releases of radionuclides because of the low levels of contamination present, high-efficiency particulate air filters on the air exhausts, and modern facility design and decontamination techniques that would minimize the potential for airborne contamination. After the completion of decontamination, most of the noninvolved workers would no longer be employed, resulting in a much lower noninvolved worker population and correspondingly lower worker population dose.

Monitoring periods would range from 76 to 300 years depending on the repository operating mode and selected operating parameters. Table 4-5 lists estimated maximum annual doses and total doses that would occur from monitoring and maintenance activities to maximally exposed individuals and potentially affected populations from subsurface radon releases. Section 4.1.7 discusses potential radiological impacts from these doses. The dose over the 70-year lifetime of the hypothetical offsite maximally exposed individual, at the southern boundary of the land withdrawal area, would be 29 to 62 millirem during monitoring and maintenance activities for the range of repository operating modes. The maximum annual dose to the offsite maximally exposed individual would be about 0.41 to 0.89 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3 to 6 percent of this standard. The hypothetical offsite maximally exposed individual would receive a higher dose than the noninvolved worker maximally exposed individual because air would be removed from the repository through exhaust shafts, which would result in more radon being carried to the exposure point for the offsite individual than to that for the noninvolved worker.

The population dose for monitoring and maintenance activities would range from 600 to 3,500 person-rem, the difference mainly reflecting the range of 76 to 300 years of postemplacement monitoring. The dose to the maximally exposed noninvolved (surface) worker, who would be at the South Portal Development Area, would range from 0.096 to 0.33 millirem for a 50-year working lifetime during monitoring and maintenance activities. The dose to the repository noninvolved (surface) worker population, which would include all surface workers (most of whom would be at the North Portal Operations Area), would range from 0.0091 to 0.05 person-rem for the monitoring period.

In general, longer periods of monitoring and maintenance activities would result in larger total releases of radon and its decay products and potentially extend these impacts to future generations of workers and the public. Highest total doses during the monitoring period for the 80-kilometer (50-mile) population and the Nevada Test Site noninvolved worker population would be under conditions of maximum ventilation and moderate waste package spacing, which would require the longest time (300 years) of ventilation and monitoring. For the other potential doses listed in Table 4-5, the highest potential total and annual doses for monitoring would be under conditions of largest waste package spacing, which would require the largest repository and have the largest radon release per year from the repository. Section 4.1.7 discusses human health impacts to the public and workers from the monitoring period.

Table 4-5. Radiation doses to maximally exposed individuals and populations during the monitoring period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual	Total	Maximum annual
Dose to public				
Offsite MEI[c] (millirem)	29	0.41	30 - 62	0.59 - 0.89
80-kilometer population[d] (person-rem)	600	8	1,500 - 3,500	11 - 17
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	0.096	0.0019	0.16 - 0.33	0.0011 - 0.0067
Yucca Mountain noninvolved worker population (person-rem)	0.0091	0.0013[f]	0.031 - 0.05	0.000034 - 0.0057[f]
Nevada Test Site noninvolved worker population[g] (person-rem)	0.033	0.00044	0.083 - 0.19	0.00021 - 0.00094

a. Numbers are rounded to two significant figures.
b. Decontamination of surface facilities during the operation and monitoring phase would last 3 years at the beginning of monitoring, which would last from 76 to 300 years.
c. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area. Values are for a 70-year lifetime.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Development Area. Values are for a 50-year onsite working lifetime.
f. Maximum annual dose occurs during the 3 years of decontamination activities when worker population is largest.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.4 Impacts to Air Quality from Closure

This section describes potential nonradiological and radiological air quality impacts during the closure phase of the proposed Yucca Mountain Repository, which would begin after the 76 to 300 years of monitoring and last 10 to 17 years. Activities during this phase would include the closure of subsurface repository facilities, the decommissioning of surface facilities, and the reclamation of remaining disturbed lands.

4.1.2.4.1 *Nonradiological Impacts to Air Quality from Closure*

During the closure phase, nonradiological air emissions would result from the backfilling and sealing of the repository subsurface and the reclamation of disturbed surface lands. Air emission sources would include the following:

- Fugitive dust emissions from the handling, processing, and transfer of backfill material to the subsurface
- Releases of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, and carbon monoxide) and particulate matter from fuel consumption
- Gaseous criteria pollutants and particulate matter from diesel-fed boilers at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Fugitive dust releases from demolishing buildings, removing debris, and reclaiming land

- Cristobalite releases associated with handling and storing excavated rock

Table 4-6 lists potential impacts at the location of the offsite maximally exposed individual from the closure of the repository for the higher- and lower-temperature operating modes.

Table 4-6. Maximum criteria pollutant and cristobalite concentrations at the land withdrawal area boundary during closure phase (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.54	0.54	0.54	0.54 - 0.55
Sulfur dioxide	Annual	80	0.11	0.11	0.15	0.15
	24-hour	365	1.4	1.4	0.38	0.38
	3-hour	1,300	9.3	9.3	0.71	0.71 - 0.72
Carbon monoxide	8-hour	10,000	4.7	4.7	0.045	0.045 - 0.046
	1-hour	40,000	31	31	0.078	0.078
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.38	0.34 - 0.37	0.76	0.67 - 0.73
	24-hour	150 (65)	5.5	5.2 - 5.4	3.7	3.4 - 3.6
Cristobalite	Annual[d]	10[d]	0.012	0.0089 - 0.0098	0.12	0.089 - 0.098

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of the highest concentrations at the accessible land withdrawal boundary regardless of direction.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Gaseous criteria pollutants would result primarily from vehicle exhaust. During the closure phase, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small, with the gaseous criteria pollutant concentrations being less than 1 percent of the applicable regulatory limits. The 24-hour PM_{10} concentrations would be about 4 percent of the regulatory limit for all operating modes. Levels of $PM_{2.5}$ should also be well below the applicable standard, because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not affect the concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

As discussed for the construction phase (see Section 4.1.2.2.1), the analysis of the closure phase assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. Table 4-6 lists estimated cristobalite concentrations to which the offsite maximally exposed individual would be exposed during closure. As noted in Section 4.1.2.2.1, there are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The postulated exposure to cristobalite from closure activities would be small, about 0.01 microgram per cubic meter or less for all three thermal load scenarios, or less than one-tenth of 1 percent (0.098) of the benchmark. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions among the operating modes.

4.1.2.4.2 *Radiological Impacts to Air Quality from Closure*

During the closure phase the only doses from releases of radionuclides to the atmosphere would be from naturally occurring radon-222 and its radioactive decay products released from the continued ventilation of subsurface facilities. The analysis assumed that subsurface ventilation would continue for the duration of the closure phase, lasting 10 to 17 years. Exposure to the noninvolved (surface) worker population would occur during the 6-year period while this group was working on surface facility closure. Exposure would continue to members of the public and a smaller number of workers throughout the period for subsurface facility closure.

Table 4-7 lists estimated annual doses and total doses from radon-222 during the closure phase to maximally exposed individuals and potentially affected populations from radionuclide releases from subsurface facilities. Section 4.1.7 discusses potential radiological impacts from these doses. The total dose to the offsite maximally exposed individual would be 3 to 9.4 millirem for the closure phase. The maximum annual dose to the offsite maximally exposed individual would be about 0.4 to 0.87 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3 to 6 percent of this standard. The population dose would be 57 to 180 person-rem for the closure phase. The dose to the maximally exposed noninvolved (surface) worker at the South Portal would be 0.014 to 0.07 millirem for the entire closure phase. The dose to the noninvolved repository (surface) worker population would range from 0.004 to 0.015 person-rem. Highest doses for this phase—both total and annual—would be under conditions of largest waste package spacing, which would require the largest repository and the longest time (17 years) to close the repository.

Table 4-7. Radiation doses to maximally exposed individuals and populations from radon-222 releases from the subsurface during closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual[c]	Total	Maximum annual[c]
Dose to public				
MEI[c] (millirem)	3	0.4	4.3 - 9.4	0.57 - 0.87
80-kilometer population[d] (person-rem)	57	7.4	83 - 180	10 - 16
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	0.014	0.0018	0.024 - 0.07	0.003 - 0.0063
Yucca Mountain noninvolved worker population (person-rem)	0.004	0.00052	0.007 - 0.015	0.00088 - 0.0014
Nevada Test Site noninvolved worker population[f] (person-rem)	0.0031	0.00041	0.0046 - 0.0099	0.00058 - 0.00089

a. Numbers are rounded to two significant figures.
b. The closure phase would begin after the 76 to 300 years of monitoring and last 10 to 17 years.
c. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Development Area.
f. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.5 Total Impacts to Air Quality from All Phases

The nonradiological air quality analysis examined concentrations of criteria pollutants in comparison to National Ambient Air Quality Standards. These standards are for periods ranging from 1 hour up to an annual average concentration of pollutant, so a “total” project impact is presented as no more than the highest single year. The highest concentrations of all criteria pollutants except PM_{10} would be less than 1 percent of applicable standards in all cases. PM_{10} would also be less than 1 percent of the applicable limits except: it would be less than 2 percent of the annual limit and 6 percent of the 24-hour limit during the construction phase; less than 2 percent of the 24-hour limit during the operation and monitoring phase; and less than 4 percent of the 24-hour limit during the closure phase.

The radiological impacts to air quality for the entire project are quantified by evaluating the doses to the populations of potentially exposed workers and members of the public. Results are not presented for impacts to individuals because the project duration (from 115 to 341 years) would be longer than the 70-year lifetime used for analysis purposes. Individual impacts for the various project activity periods (as long as 50 years for workers and 70 years for the public for the longer monitoring period) are discussed in the previous sections.

Table 4-8 lists total radiological air quality impacts for the entire Yucca Mountain Repository project. This table includes impacts for the higher-temperature repository operating mode and the range of impacts for the lower-temperature operating mode. The higher-temperature operating mode would have lower radiological air quality impacts, because it would have the shortest project duration (115 years), smallest excavated repository volume and therefore lowest releases of naturally occurring radon-222 and decay products, the primary dose contributor.

Table 4-8. Total radiation doses to exposed individuals and populations for all phases.[a,b,c]

	Operating mode			
	Higher-temperature		Lower-temperature[d]	
Release	Entire project	Annual	Entire project	Annual
Dose to public				
MEI[e] (millirem)	31	0.73	44 - 62	1 - 1.3
80-kilometer population[f] (person-rem)	930	14	1,900 - 3,900	20 - 26
Dose to noninvolved workers (person-rem)				
Maximally exposed noninvolved worker[e] (millirem)	30	2	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker[g] population	1.7	0.1	1.7 - 2.4	0.12 - 0.13
Nevada Test Site noninvolved worker population[h]	0.048	0.00063	0.1 - 0.21	0.0009 - 0.0012

a. Numbers are rounded to two significant figures.
b. The duration of all project phases (construction, operation and monitoring, and closure) would range from 115 to 341 years.
c. Section 4.1.7.5.3 describes radiological health impacts.
d. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
e. MEI = maximally exposed individual. The public MEI would be exposed 70 years and the noninvolved worker MEI exposed 50 years.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
g. For air quality impacts, noninvolved workers include those at the repository surface who could be exposed to releases of radon-222 and its decay products from the exhaust shafts.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.3 IMPACTS TO HYDROLOGY

The following sections describe environmental impacts to the hydrology of the Yucca Mountain region, first from performance confirmation activities (Section 4.1.3.1), then from construction, operation and monitoring, and closure actions. The latter actions are presented in terms of surface water (Section 4.1.3.2) and groundwater (Section 4.1.3.3). Chapter 5 discusses long-term postclosure impacts resulting from repository performance.

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction and operation activities that would be susceptible to erosion, areas affected by permanent changes in flow, and downstream areas that would be affected by eroded soil or potential spills of contaminants. The analysis of surface-water impacts considered known perennial and intermittent lakes, surface streams, and washes.

The analysis assessed groundwater impacts to determine the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability of groundwater for use during construction and operations, and the potential that such use would affect other users. The region of influence for this analysis included aquifers under the areas of construction and operations that DOE could use to obtain water and downstream aquifers that repository use or long-term releases from the repository could affect. The evaluation of groundwater impacts considered perennial yields of groundwater resources in comparison to known uses and requirements.

4.1.3.1 Impacts to Hydrology from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would be unlikely to cause large impacts to the surface hydrology at the Yucca Mountain site, where there are no perennial streams or other permanent surface-water bodies. As during site characterization, DOE would design roads or other surface disturbances to minimize alterations to natural flowpaths and nearby washes (such as Drill Hole Wash). (See Section 4.1.4.2 and Chapter 11 for discussions of protection of waters of the United States.)

The preconstruction testing and performance confirmation studies would not adversely affect groundwater quality because DOE would use only limited quantities and types of hazardous materials, and activities involving such materials would be in strict accordance with applicable regulations and DOE Orders. State and Federal environmental, health, and safety regulations, as well as its own internal rules would require DOE to manage hazardous materials carefully and to clean up and report any measurable spills or releases promptly. Thus, the control of hazardous materials would be such that the potential for groundwater contamination would be very low.

DOE would use existing groundwater wells to support performance confirmation activities (for example, wells J-12 and J-13). In addition, it could use the existing C-well complex for aquifer testing and for a backup water supply. The Department expects water use from wells J-12 and J-13 to be similar to or less than that experienced during site characterization, which averaged about 0.093 million cubic meters (75 acre-feet) a year from 1993 through 1997 (not including test pumping at the C-well complex) (see Table 3-16). This would equal approximately 2 to 9 percent of the estimated perennial yield of the hydrographic basin (Jackass Flats) of 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet) a year (see Table 3-11). Therefore, adverse effects on the quantity of groundwater resources would be unlikely. DOE could conduct pump tests of the aquifer at the C-well complex during performance confirmation activities. Under such tests, the amount pumped probably would be similar to that pumped during site characterization [about 0.23 million cubic meters (190 acre-feet) per year]. Even with this additional quantity, water demand would still be well below the lowest estimates of the basin's perennial yield, and DOE would manage water withdrawn from the C-well complex as part of aquifer testing in the same manner it has used for site characterization activities (that is, discharged to a spreading basin with State of Nevada concurrence and credit for groundwater recharge).

4.1.3.2 Impacts to Surface Water from Construction, Operation and Monitoring, and Closure

There are no perennial streams or other permanent surface-water bodies in the Yucca Mountain vicinity. The occurrence of natural surface water is limited to short periods when precipitation lasts long enough or is of high enough intensity to generate runoff to the natural drainage channels. In rare instances, runoff from the area of the proposed repository and support facilities could reach such channels as Drill Hole Wash, then flow to Fortymile Wash, and eventually reach the Amargosa River. Under most precipitation events, however, water simply soaks into the ground and is usually lost to evapotranspiration or, if there is enough to accumulate in drainage channels, soaks into the dry washes before traveling far, becoming potential recharge in these localized areas. Other potential sources of surface water associated with the

Proposed Action, such as the water used for dust suppression, would be a result of pumping groundwater to the surface.

The surface-water impacts of primary concern are related to the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage
- Impacts to floodplains

Discharges of Water to the Surface

During the 5-year initial construction phase, and during the operations period that would follow (lasting 24 years or 50 years if surface aging was used), sources of surface water other than precipitation would be limited primarily to the water DOE would use for dust suppression on the surface and below ground (with accumulations pumped back to the surface). Sanitary sewage, which would be piped to septic tank and drainage field systems, would not produce surface water. In addition, DOE would pump fresh water (groundwater) at the site and store it in tanks.

DOE has evaluated dust suppression actions during characterization efforts at the Yucca Mountain site for their potential to cause deep infiltration of water (DIRS 102547-CRWMS M&O 1997, pp. 51 to 53 and 73). The evaluation concluded that the amount of water actually used for dust suppression activities during site characterization has not caused water to penetrate the underlying rock. Studies at the site on infiltration capacities of natural soils (DIRS 100147-Flint, Hevesi, and Flint 1996, pp. 57 to 59) show that runoff or deep infiltration would not occur as a result of water applications for dust suppression. DOE would establish controls as necessary to ensure that water application for subsurface and surface dust control did not affect repository performance or result in large impacts.

Water would be pumped from the surface facilities to the subsurface during the construction phase and operations period while subsurface development continued. DOE would collect excess water from dust suppression applications and water percolating into the repository drifts, if any, and pump it to the surface, generating another source of surface water. Water pumped from the subsurface would go to an evaporation pond at the South Portal Development Area. The pond would be lined with heavy plastic to prevent infiltration or water loss. Table 4-9 lists discharge estimates to the South Portal evaporation pond for the higher- and lower-temperature operating modes. During the operations period, the quantity of water discharged would vary in proportion to the amount of subsurface excavation. Annual discharges under the lower-temperature operating mode would increase in comparison to those from the higher-temperature operating mode because of increased waste package spacing and the associated increase in drift excavation. DOE would investigate the feasibility of recycling all, or a portion, of this water.

The operation of heating and air conditioning systems at the North Portal Operations Area would result in the generation of wastewater (primarily from cooling tower blowdown and water softener regeneration) that DOE would discharge to the North Portal evaporation pond, which would be lined with heavy plastic. In addition, water collected from the emplacement side of the subsurface area, if any, would be pumped to this pond after verification that it was not contaminated. Table 4-10 lists the estimated discharges to the North Portal evaporation pond for the operating modes during the operations period. The estimates of annual discharge would change under the lower-temperature operating mode depending on the specific operating parameters used. These changes would be due primarily to a small change in the estimated size (total floor space) of the facilities.

The South Portal evaporation pond would be double-lined with polyvinyl chloride and would have a leak detection system (DIRS 102303-CRWMS M&O 1998, p. 16). The North Portal evaporation pond, which would be primarily for cooling and heating process water, would, at a minimum, have a polyvinyl

Table 4-9. Annual water discharges to South Portal evaporation pond.[a,b]

Phase	Operating mode: Higher-temperature[a,b]	Operating mode: Lower-temperature[a,c]
Construction		
Discharge (cubic meters)[d]	6,800	8,500 - 9,000
Duration (years)	5	5
Operations period		
Discharge (cubic meters)	3,500	4,400 - 7,500
Duration (years)	22[e]	22[e]

a. Estimated at 13 percent of the process water pumped to the subsurface based on Exploratory Studies Facility construction experience.
b. Source: DIRS 150941-CRWMS M&O (2000, pp. 6-7 and 6-12).
c. Source: DIRS 155515-Williams (2001, pp. 13 and 17; Parts 1 and 2, pp. 5 and 9).
d. To convert cubic meters to gallons, multiply by 264.18.
e. Discharge to this pond is during subsurface development activities only.

chloride liner (DIRS 102303-CRWMS M&O 1998, pp. 16 and 28). With proper maintenance, both ponds should remain intact and would have no effect on the site. DOE would build a third, much smaller evaporation pond, as appropriate, at the concrete batch plant to facilitate collection and management of equipment rinse water. Chapter 9 discusses mitigation measures associated with the Proposed Action.

Table 4-10. Annual water discharges to North Portal evaporation pond during operations period.

Factor	Operating mode: Higher-temperature[a]	Operating mode: Lower-temperature[a,b]
Discharge (cubic meters)[c]	34,000	31,000 - 36,000
Duration (years)	24	24

a. Source: DIRS 152010-CRWMS M&O (2000, p. 52).
b. Source: DIRS 155516-Williams (2001, p. 4)
c. To convert cubic meters to gallons, multiply by 264.18.

Other uses of water during the operations period would occur in the repository facilities and would have little, if any, potential to generate surface water. These sources include the washdown stations and the pools in the Waste Handling Building. Water from either of these sources would be managed as liquid low-level radioactive waste and treated in the Waste Treatment Building. Water from the treatment process would be recycled to the extent practicable, and residues and solids would be prepared for offsite shipment and disposal.

The quantity of water discharges to the surface during the monitoring period and from closure would be similar to or less than those discussed for the initial construction phase and operations period. The evaporation ponds would no longer be in use but other manmade sources of surface water should be very similar; water storage tanks would still be in use, there would be sanitary sewage, and dust suppression activities would occur.

Potential for Contaminant Spread to Surface Water

The potential for contaminants to reach surface water would generally be limited to the occurrence of a spill or leak followed by a rare precipitation or snow melt event large enough to generate runoff. DOE would design each facility that would contain radioactive material at the repository site such that flooding would not threaten material in the facility. Consistent with DOE Order 6430.1A*, General Design Criteria*, Nuclear Regulatory Commission licensing requirements, and national standards such as those of the American National Standards Institute, facilities in the Radiologically Controlled Area (for the management of radioactive materials) would be built to withstand the probable maximum flood. For example, if the footprint of a facility in the Radiologically Controlled Area was within the predicted natural inundation level of the probable maximum flood, one way to protect the facility would be to build up its foundation so it would be above the flood level and associated debris flows (DIRS 102303-CRWMS M&O 1998, pp. 32 to 37). Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. Inundation levels expected from a 100-year, 500-year, regional maximum, or even probable maximum flood would represent no hazard to the proposed repository subsurface facilities, the portals of which would be at higher elevations than the flood-prone areas (DIRS 151945-CRWMS M&O 2000, p. 7.3-4 and Figure 7.3-3).

DOE would minimize the potential for a contaminant spread by managing spills and leaks in the proper and required manner. Activities at the site would adhere to a Spill Prevention, Control, and Countermeasures Plan [DIRS 104903-K/PB (1997, all) is an example] to comply with environmental regulations and to ensure best management practices. The plan would describe the actions DOE would take to prevent, control, and remediate spills. It would also describe the reporting requirements that would accompany the identification of a spill. As an additional measure to reduce the potential for contaminant release to surface water, DOE would build two stormwater retention basins near the North Portal Operations Area, one for the Radiologically Controlled Area and one for the balance-of-plant facilities. The basin for the Radiologically Controlled Area would contain the runoff from a storm consistent with the probable maximum flood. The basin for the balance-of-plant area would contain the runoff from a storm consistent with a 100-year flood.

The primary sources of potential surface-water contaminants during both the construction and the operation and monitoring phases would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Fuel oil storage tanks would be in place relatively early in the construction phase. Each would be constructed with an appropriate containment structure (consistent with 40 CFR Part 112). Other organic materials such as paints, solvents, strippers, and concrete additives would be present during the construction phase but in smaller quantities and much smaller containers.

The operation and monitoring phase would involve the use of other chemicals, particularly in the Waste Treatment Building, where the liquid low-level radioactive waste treatment process, for example, would include the use of liquid sodium hydroxide and sulfuric acid. In addition, this phase would require relatively small quantities of cleaning solvents [up to about 1,300 liters (330 gallons) per year] (DIRS 152010-CRWMS M&O 2000, p. 51). Because these materials would be used and stored inside buildings and managed in accordance with applicable environmental, health, and safety standards and best management practices, there would be little potential for contamination to spread through contact with surface water.

In addition, liquid low-level radioactive waste present in the Radiologically Controlled Area would be treated in the Waste Treatment Building to stabilize such material with cement or grout before it left the facility. Similarly, hazardous waste and mixed waste would be maintained and moved in closed containers. These conditions would minimize the potential for spills and leaks that could lead to contaminant spread.

Radioactive materials present during the operation and monitoring phase would be managed in the Radiologically Controlled Area of the North Portal Operations Area. This would include the Carrier Parking Area and Carrier Preparation Building across Midway Valley Wash to the northeast, and the aging pads if used for the lower-temperature operating mode. The radiological materials would always be in containers or casks except when they were in the Waste Handling and Waste Treatment Buildings. In those buildings, facility system and component design would prevent inadvertent releases to the environment; drainlines would lead to internal tanks or catchments, air emissions would be filtered, fuel pools would have secondary containment and leak detection, and other features would have similar safety or control components. If a lower-temperature operating mode with surface aging was implemented, the fuel blending pools (total capacity of 5,000 MTHM) would be eliminated from the design. A fuel transfer pool associated with the assembly transfer system would still be present, but would represent a much smaller volume of water. Elimination of the blending pools would eliminate a source of potential water releases, but in all cases the probability of leakage from any of these pools would be very low, given current design engineering, and construction standards and the importance of leak prevention.

During the operation and monitoring phase a surface environmental monitoring system would monitor the surface areas and groundwater for radioactive and hazardous substance release (DIRS 101779-DOE 1998, Volume 2, p. 4-37). It would also monitor facility effluents and testing wells for the presence of radiological or other hazardous constituents that could indicate a release from an operation activity. The combination of minor sources of surface water and the prevention and control of contaminant releases would limit the potential for contaminant spread by surface water.

Monitoring and maintenance activities after the completion of emplacement would involve a decrease in general activities at the site and, accordingly, less potential for spills or releases to occur. Decontamination actions that would follow emplacement could present other risks, due to the possible presence of decontamination chemicals and the start of new work activities. DOE would continue to use controls, monitoring, response plans and procedures, and regulatory requirements to limit the potential for spills or releases to occur from these activities.

The potential for contaminant spread would be limited during the closure phase and would be reduced further during postclosure care of the site. As in the other phases, engineering controls, monitoring, and release response requirements would limit the potential for contaminants to reach surface water.

Potential for Changes to Surface Water Runoff or Infiltration Rates

Construction activities that disturbed the land surface would alter the rate at which water could infiltrate the disturbed areas. A maximum of about 2.8 square kilometers (690 acres) of land would be disturbed during the construction and operation and monitoring phases of the higher-temperature operating mode. Including land already disturbed during the characterization activities, the total would be about 4.3 square kilometers (1,060 acres). The amount of newly disturbed land would be about 4.0 to 4.5 square kilometers (990 to 1,100 acres) under the lower-temperature operating mode. Depending on the type of disturbance, the infiltration rate could increase (for example, in areas with loosened soil) or decrease (for example, in areas where construction activities had compacted the soil or involved the installation of relatively impermeable surfaces like asphalt pads, concrete surfaces, or buildings). Most of the land disturbance during construction would result in surfaces with lower infiltration rates; that is, the surfaces would be less permeable than natural soil conditions and would cause an increase in runoff. However, DOE expects the change in the amount of runoff actually reaching the drainage channels to be relatively minor, because repository construction would affect a relatively small amount of the natural drainage area. For example, almost all of the area that would be disturbed at the proposed repository site is drained by Drill Hole Wash, which includes Midway Valley Wash as a major tributary. The maximum new disturbance of 4.5 square kilometers (1,100 acres) would be small (less than 12 percent) in comparison to the approximate 40 square kilometers (9,900 acres) that comprise the drainage area of Drill Hole Wash by the time it reaches Fortymile Wash (DIRS 102783-Squires and Young 1984, p. 2).

Monitoring and maintenance activities would not disturb additional land and, therefore, would have no notable impacts to runoff rates in the area. Reclamation of previously disturbed land would restore preconstruction runoff rates.

DOE anticipates that closure activities would disturb only land that had been previously disturbed during earlier phases. The removal of structures and impermeable surfaces would decrease runoff from these areas and should put them in a condition closer to that of the surrounding natural surfaces. Reclamation efforts such as topsoil replacement and revegetation should help restore the disturbed areas to nearly natural conditions in relation to infiltration and runoff rates. The construction of monuments as long-lasting markers of the site use would be likely to make their locations impervious to infiltration but, as described above, change in runoff from the relatively small impervious areas would be small in comparison to the total drainage area.

Potential for Altering Natural Surface-Water Drainage

Construction activities can alter natural drainage systems if they (1) increase the erosion and sedimentation process (material eroded from one location in the drainage system is subsequently deposited in another location), or (2) place a structure, facility, or roadway in a drainage channel or flood zone. Section 4.1.4.4 discusses erosion issues. The focus of this section is the planned construction of structures, facilities, or roadways over natural drainage channels.

Pursuant to Executive Order 11988, *Floodplain Management*, each Federal agency is required, when conducting activities in a floodplain, to take action to reduce the risk of flood damage; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. DOE regulations implementing this Executive Order are at 10 CFR Part 1022.

Repository-related structures could affect small drainage channels or washes. DOE expects to control surface-water drainage in these washes with minor diversion channels, culverts, or similar drainage control measures. Some transportation-related construction, operation, and maintenance actions would occur in the floodplains of as many as four washes in the Yucca Mountain vicinity. Construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. Appendix L contains a floodplain/wetlands assessment that describes in detail the actions that DOE could take. The analysis indicated that consequences of the actions DOE could take in or near the floodplains of these four washes would be minor and unlikely to increase the impacts of floods on human health and safety or harm the natural and beneficial values of the affected floodplains. It also indicated that there are no delineated wetlands at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on the route DOE selected.

Closure of the repository should involve no actions that would alter natural drainage beyond those from the other phases. Areas where facilities were removed would be graded to match the natural topography to the extent practicable. Monuments would not be constructed in locations where they would alter important drainage channels or patterns and, in the process, back up or divert any meaningful volume of runoff.

4.1.3.3 Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

This section identifies potential impacts to groundwater. Section 3.1.4 describes existing groundwater characteristics and uses in the Yucca Mountain vicinity. The potential impacts discussed in this section would be associated with the repository project, which would include construction, operation and monitoring, and closure. Chapter 5 describes potential impacts as a result of the repository's long-term performance after closure. The following impacts would be of primary concern while the repository was open:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer
- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones
- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

This section discusses these potential impacts in general terms, primarily in relation to changes from existing conditions.

Infiltration Rate Changes

As discussed in Section 4.1.3.2, surface-disturbing construction activities would alter infiltration rates in the repository area. In the Yucca Mountain environment, water rarely travels long distances on the surface before infiltrating into the ground or evaporating. If construction activities resulted in disturbed land that was loose or broken up, local infiltration would increase and the amount of runoff reaching nearby drainage channels would decrease accordingly. Conversely, completed construction that involved either compacted soil or facility surfaces (concrete pads, asphalt surfaces, etc.) would result in less local infiltration and more water available to reach the drainage channels and then infiltrate into the ground. However, the location where infiltration takes place can have an effect on what happens to the water. That is, in some locations the water would be more likely to contribute to deep infiltration and possibly even to recharge to the aquifer.

In the semiarid environment in the Yucca Mountain vicinity, surface areas where meaningful recharge to the aquifer can occur are generally places such as Fortymile Wash (Section 3.1.4.2.2), which collects runoff from a large drainage area. Enough water can accumulate there to cause deep infiltration and occasional recharge. There is not enough precipitation or runoff in most other areas to generate infiltration deep enough to prevent its loss to evapotranspiration between precipitation events. In general, this will be the case even when land disturbance causes an increase in local infiltration. The most likely way that recharge could be affected would be for land disturbance to cause additional runoff (as from constructed facilities) that could accumulate in areas such as Fortymile Wash, and the effect would be a potential for increased recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small.

Surface disturbances could change infiltration rates in areas where the layer of unconsolidated material is thin and the disturbance resulted in the exposure of fractured bedrock. Cracks and crevices in the bedrock could provide relatively fast pathways for the movement of water to deep parts of the unsaturated zone (DIRS 151945-CRWMS M&O 2000, p. 8.9-8), where the water would be less susceptible to evapotranspiration. These effects would be applicable to the Emplacement and Development Shaft Operations Areas, which would be on steeper terrain, uphill from the South Portal Development Area and North Portal Operations Area, where the depth of unconsolidated material is likely to be thin. However, the amount of disturbed land would be small in comparison to the surrounding undisturbed area, and any net change in infiltration would be small.

Subsurface activities would have the potential to affect the amount of water in the unsaturated zone that could infiltrate more deeply, possibly even as recharge to the aquifer. These activities would include measures to minimize the quantities of standing or infiltrating water in the repository by pumping it to the surface for evaporation. Potential sources of this water could include water percolating in from the unsaturated zone and water pumped from the surface for underground dust control measures. The latter should involve the largest volume by far, much of which would be brought to the surface with the excavated rock generated by tunnel boring machines. Excess water in the subsurface would evaporate (the underground areas would be ventilated), be collected and pumped to the surface, or be lost as infiltration to cracks and crevices in the rock. During excavation of the Exploratory Studies Facility, DOE tracked water use and used water tracers to help track its movement. The purpose of these actions was to minimize loss of this water to the subsurface environment and to ensure that subsurface water use did not adversely affect either future repository performance or ongoing site investigations (DIRS 102197-CRWMS 1997, all). This careful use of water in the subsurface would continue during additional repository excavation. Given the mechanisms to remove the water (excavated rock removal, ventilation, and pumping) and the careful use of water in the subsurface, along with the relatively minor importance of Yucca Mountain recharge to the local and regional groundwater system, DOE expects perturbations in recharge through Yucca Mountain to be of small impact to the local and regional groundwater system.

No additional land disturbance would occur from monitoring and maintenance activities and, therefore, there would be no notable impacts to infiltration rates in the area. There would be no additional land disturbance during closure. The implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. If DOE built a monument (or monuments) to provide a long-lasting marker for the site, its location could be impermeable and thus could generate minor amounts of additional runoff to drainage channels.

Potential for Contaminant Migration to Groundwater

Section 4.1.3.2 discusses the types of potential contaminants that could be present at the repository surface facilities during the various phases of its active life. It also discusses the possibility of spills or releases of these materials to the environment.

To pose a threat to groundwater, a contaminant would have to be spilled or released and then carried down either by its own volume or with infiltrating water. The depth to groundwater, the thickness of alluvium in the area, and the arid environment would combine to reduce the potential for a large contaminant migration, as would adherence to regulatory requirements and plans such as a Spill Prevention Control and Countermeasure Plan (see Section 4.1.3.2). Section 4.1.8 further discusses the potential for onsite accidents that could involve a release of contaminants. Chapter 5 discusses the long-term postclosure release of contaminants from the waste packages emplaced in the repository.

Groundwater Resources

The quantity of water necessary to support the Proposed Action would be greatest during the initial construction phase and the operation and monitoring phase. Peak demand would occur while DOE was emplacing nuclear material in completed drifts (tunnels) at the same time it was developing other drifts. Table 4-11 summarizes the estimated water demands during these two phases and during closure. Water demand during construction would depend on the operating mode employed. The lower-temperature operating mode would involve emplacement of less spent fuel per unit of repository footprint area, which correlates with increased excavation and increased water to support that excavation.

Table 4-11. Annual water demand for construction, operation and monitoring, and closure.[a]

Phase	Duration (years)	Water demand (acre-feet per year)[a]	
		Higher-temperature	Lower-temperature
Construction	5	160	190 - 210
Operation and monitoring			
Operations period[b]			
Emplacement and development	22	230	250 - 290
Subsequent emplacement only	2 or 28	180	90 - 190
Monitoring period			
Initial decontamination	3	220	200 - 230
Subsequent monitoring and caretaking	73 - 300	6	3 - 6
Closure	10 - 17	81	70 - 84

a. To convert acre-feet to cubic meters, multiply by 1,233.49. Acre-feet are presented because of common public knowledge of this area.

b. Development of the subsurface area would last 22 years for the Proposed Action and emplacement would continue another 2 years without aging. If aging was included, emplacement would not be completed until 28 years beyond the completion of development.

As listed in Table 4-11, water demand during the initial construction phase would range from about 200,000 to 260,000 cubic meters (160 to 210 acre-feet) per year under the range of operating modes. Water demand during the operations period would also vary by operating mode and could range from about 280,000 to 360,000 cubic meters (230 to 290 acre-feet) per year. Once subsurface development was complete and only emplacement was occurring, the estimated annual water demand would range from 110,000 to 230,000 cubic meters (90 to 190 acre-feet). The low end of this range would occur only if the aging facility was included, but it would last for about 26 years while the spent nuclear fuel on the surface pad completed its 30-year cooldown period and DOE gradually moved it to the subsurface. The first 3 years of the monitoring period would include facility decontamination efforts and would require water at a rate varying from 250,000 to 280,000 cubic meters (200 to 230 acre-feet) per year. After the first 3 years, water demand would drop substantially to estimated levels of only 3,700 to 7,400 cubic meters (3 to 6 acre-feet) for the duration of the monitoring period. The closure phase would require about 86,000 to 100,000 cubic meters (70 to 84 acre-feet) per year.

The water demand would be met by pumping from wells in the Jackass Flats hydrographic area, using existing wells J-12, J-13, and the C-well complex. Nevada Test Site activities in this same area also withdraw water from this hydrographic area. This ongoing demand from Nevada Test Site activities has an effect on the affected environment and would continue to represent part of the demand from the Jackass Flats hydrographic area. Consequently, this additional water demand is discussed here and as part of the cumulative impacts in Chapter 8.

DOE evaluated potential impacts of the water demands on area groundwater resources by three methods:

- Consideration of impacts observed or measured during past water withdrawals
- Comparison of the proposed demand to the perennial yield of the aquifer supplying the water
- Groundwater modeling efforts to assess any changes the proposed demand would have on groundwater elevations and flow patterns

Groundwater Demand During Construction

During the initial construction phase, the estimated water demand from the Jackass Flats hydrographic area would be about 540,000 to about 600,000 cubic meters (440 to 490 acre-feet) a year, including the ongoing demand from Nevada Test Site activities [projected to be 340,000 cubic meters (280 acre-feet) a year (DIRS 103226-DOE 1998, Table 11-2, p. 11-6)]. This quantity is very similar to the roughly 490,000 cubic meters (400 acre-feet) withdrawn from the Jackass Flats area in 1996 (see Chapter 3, Table 3-16). The level of water demand during the construction phase probably would result in declines in water levels in the production wells and nearby. DOE expects the amount of decline to be similar to the groundwater level fluctuations discussed in Chapter 3, Section 3.1.4.2.2 (see Table 3-17), during which elevation decreases as large as 6 to 12 centimeters (2.4 to 4.7 inches) occurred in the production wells over a 6-year period. However, this decline would diminish to undetectable levels as the distance from the repository increased and would result in very small effects to the overall groundwater system.

Effect of Operations on Groundwater Perennial Yield

As the Proposed Action would move from construction into the operation and monitoring phase, groundwater withdrawal rates would increase. The following discussion of impacts centers on comparisons to the perennial yield of the groundwater basin supplying the water.

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir. As discussed in Chapter 3, Section 3.1.4.2, the estimated perennial yield of the aquifer in the Jackass Flats hydrographic area is between 1.1 million and 4.9 million cubic meters (880 and 4,000 acre-feet) (DIRS 104954-Thiel 1997, p. 8). However, as indicated in footnote f to Table 3-11 in Chapter 3, the low estimate of perennial yield for Jackass Flats is accompanied by the qualification that 370,000 cubic meters (300 acre-feet) is attributed to the eastern one-third of the area, and 720,000 cubic meters (580 acre-feet) is attributed to the western two-thirds where wells J-12 and J-13 are located. This distinction was made to be consistent with the belief of some investigators that the two portions of Jackass Flats have different general flow characteristics. Assuming this is correct, the most conservatively low estimate of perennial yield applicable to the location of wells J-12 and J-13 would be 720,000 cubic meters (580 acre-feet). The highest estimated water demand during the operation and monitoring phase would not exceed this lowest estimate of perennial yield, and it would represent only about 7 percent of the higher estimate of perennial yield.

A past DOE application for a water appropriation from Jackass Flats resulted in a State Engineer's ruling (DIRS 105034-Turnipseed 1992, pp. 9 to 11) that described the perennial yield of Jackass Flats (Hydrographic Area 227A) as 4.9 million cubic meters (4,000 acre-feet). The same ruling identified the estimated annual recharge for the western two-thirds of this hydrographic area as 720,000 cubic meters (580 acre-feet). Based on this information, the estimates of perennial yield for this hydrographic area range from consideration of only the amount of recharge that occurs in the area to inclusion of underflow that enters the area from upgradient groundwater basins. If the groundwater is basically in equilibrium under current conditions (which should be a reasonable assumption based on the stability of the water table elevation), then withdrawing more than 720,000 cubic meters probably would result in additional underflow entering the immediate area to maintain the equilibrium level. Under this scenario, pumping more than 720,000 cubic meters from the western portion of Jackass Flats would be unlikely to cause a depletion of the reservoir, and instead could result in shifting of the general groundwater flow patterns. Because the amount pumped would be much less than the upper estimates of perennial yield (that is, the total amount of available water moving through the area, not just the recharge from precipitation), changes in general flow patterns probably would be small.

With the addition of repository water usage to the baseline demands from Nevada Test Site activities, the highest estimated demand from the Jackass Flats area during the initial construction phase would be about 600,000 cubic meters (490 acre-feet) per year. This demand would be below the lowest estimate of the area's perennial yield [720,000 cubic meters (580 acre-feet) for the western two-thirds of Jackass Flats]. Maximum repository water demands would occur during the operations period (Table 4-11), which when combined with the baseline demands from Nevada Test Site activities would approach but still be below the lowest perennial yield estimate. None of the water demand estimates would approach the high estimates of perennial yield [4.9 million cubic meters (4,000 acre-feet)].

On a regional basis in the Alkali Flat-Furnace Creek groundwater basin, the heaviest water demand is in the Amargosa Desert. Over the period of the repository project's need for water, additional water consumption in upgradient hydrographic areas would to some extent decrease the availability of water in the valley (DIRS 103099-Buqo 1999, pp. 37, 38, and 52). That is, consumption would not necessarily exceed the perennial yield of the Jackass Flats hydrographic area, but it could reduce the long-term amount of underflow that would reach the Amargosa Desert, effectively decreasing the perennial yield of that hydrographic area. However, the maximum projected demands for the repository and the Nevada Test Site during the construction phase [about 600,000 cubic meters (490 acre-feet) a year] and the operation and monitoring phase [about 700,000 cubic meters (570 acre-feet)] would be small in comparison to the 17 million cubic meters (14,000 acre-feet) pumped in the Amargosa Desert annually from 1995 through 1997 (see Table 3-11). The demand of the repository and the Nevada Test Site would be even a smaller fraction of the perennial yield of 30 million to 40 million cubic meters (24,000 to 32,000 acre-feet) in the Amargosa Desert.

Potential Changes to Groundwater Elevation

Two separate modeling efforts have assessed potential changes to groundwater elevations and flow patterns as a result of water demands from the proposed repository action. One study (DIRS 145966-

CRWMS M&O 2000, all) was performed by Thiel Engineering Consultants for DOE; the other study (DIRS 145962-Tucci and Faunt 1999, all) was performed by the U.S. Geological Survey. Both efforts included the modeling of baseline conditions that included historical water withdrawals from the Jackass Flats area followed by modeling of future water withdrawals that include the baseline and an additional annual water demand of 530,000 cubic meters (430 acre-feet) for the proposed repository. The studies focused on the predicted differences between the baseline and future simulations in the groundwater flow regime of Jackass Flats and surrounding hydrographic areas, particularly the Amargosa Desert (see Figure 3-17). The Thiel Engineering Consultants study included the use of transient models (DIRS 145966-CRWMS M&O 2000, p. 2) to project changes in groundwater levels and flow patterns. It utilized several different assumed groundwater withdrawal scenarios over this area, with and without the water demand for the repository project, and simulated the withdrawal scenarios for 100 years. The U.S. Geological Survey effort compared the results of two steady-state simulations (baseline and predictive future) of the regional groundwater flow system. Results of the simulations indicated that there would be groundwater elevation differences (between conditions with and without the Proposed Action) as described in the following summary statements:

- The Thiel Engineering Consultants study predicted a water elevation decrease of up to 3 meters (10 feet) within about 1 kilometer (0.6 mile) of the Yucca Mountain production wells as a result of the Proposed Action's water demand (DIRS 145966-CRWMS M&O 2000, p. 86). The U.S. Geological Survey model resulted in similar projections, predicting a water level decrease of less than 2 meters (6.6 feet) at distances of a few kilometers from the production wells (DIRS 145962-Tucci and Faunt 1999, p. 13).

- The models predicted water elevation decreases at the town of Amargosa Valley ranging from less than 0.4 meter (1.2 feet) (DIRS 145966-CRWMS M&O 2000, all) to 1.1 meters (3.6 feet) (DIRS 145962-Tucci and Faunt 1999, p. 13).

- Both models generated predictions of the reduction in underflow from the Jackass Flats hydrographic area to the Amargosa Desert hydrographic area that would result from the Proposed Action. The Thiel Engineering Consultants (DIRS 145966-CRWMS M&O 2000, p. 89) study estimates a flow reduction of about 160,000 cubic meters (130 acre-feet) per year after 100 years of pumping. The U.S. Geological Survey (DIRS 145962-Tucci and Faunt 1999, p. 13) effort estimates 180,000 cubic meters (150 acre-feet) per year at steady-state conditions.

The Thiel Engineering Consultants modeling effort looked at numerous locations and pumping scenarios throughout the groundwater region. The results indicated that in all areas of the Amargosa Desert, the decreases in groundwater elevation attributed to the Proposed Action would be minor in comparison to those simulated for the areas without the Proposed Action (DIRS 145966-CRWMS M&O 2000, pp. 173 to 184). Both models evaluated a hypothetical Yucca Mountain Project water demand of 530,000 cubic meters (430 acre-feet) per year, which is the quantity planned for the site's application for a water appropriation. As listed in Table 4-11, the highest estimate of the Proposed Action's annual water demand is only about 67 percent of this quantity. Had this smaller number been used in the models, a corresponding decrease in the predicted effects would have resulted. The Proposed Action's higher periods of water demand [that is, periods with annual water demand near or above 250,000 cubic meters (200 acre-feet)] would total only about 30 years compared to the 100 years of demand at the higher rate used in the Thiel Engineering Consultants study.

Monitoring Period

Water demand for monitoring and maintenance activities would be much less than that for emplacement and development activities, particularly after the completion of decontamination activities, which would take place during the first 3 years of the monitoring period. Routine monitoring and maintenance activities would involve minimal water needs.

Closure Phase

The annual demand during closure would vary by a small amount based on the operating mode used, but would be less than 30 percent of the maximum demand during the operation and monitoring phase and, similarly, would have minor impacts on groundwater resources.

Summary of Impacts to Hydrology

The conclusions of the evaluations discussed in this section are as follows:

- Repository operation would result in minor changes to runoff and infiltration rates.

- The potential for flooding at the repository site is extremely small.

- Water demand under highest consumption conditions would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats groundwater basin. The highest demand conditions in combination with ongoing Nevada Test Site demand from the same basin would also be below the lowest estimates of perennial yield.

- The combined water demand of the repository and the Nevada Test Site would, at most, have minor impacts on the availability of groundwater in the Amargosa Valley in comparison to the quantities of water already being withdrawn there.

DOE filed an application for permanent water rights with the State of Nevada for the projected water needs to meet DOE's responsibilities under the NWPA. Uses for the water would include, but not be limited to, road construction, facility construction, drilling, dust suppression, drift and pad construction, testing, culinary, domestic, and other related site uses. On February 2, 2000, the Nevada State Engineer denied the application on the basis that the proposed use threatens to prove detrimental to the public interest because the proposed use (that is, supporting the repository action) is prohibited by existing State law. On March 2, 2000, DOE filed an appeal of the State Engineer's decision (DIRS 151945-CRWMS M&O 2000, pp. 9.5-5 and 9.5-6). On October 15, 2001, the U.S. Court of Appeals (9th Circuit) remanded the case back to the Nevada District Court for a hearing on the merits. At the time this EIS was prepared, the appeal was still in process and a final outcome for the water appropriation application had not been determined.

4.1.4 IMPACTS TO BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for affecting sensitive species (plants and animals) and their habitats, including areas of critical environmental concern; sensitive, threatened, or endangered species, including their habitats; jurisdictional waters of the United States, including wetlands; and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of game animals. DOE expects the overall impacts to biological resources to be very small. Biological resources in the Yucca Mountain region include species typical of the Mojave and Great Basin Deserts and generally are common throughout those areas. Neither the removal of vegetation from the small area required for the repository nor the very small impacts to some species would affect regional biodiversity and ecosystem function.

Section 4.1.4.1 describes potential impacts to biological resources and soils from preconstruction testing and performance confirmation activities. Section 4.1.4.2 describes potential impacts to biological resources from construction, operation and monitoring, and closure. Section 4.1.4.3 describes the evaluation of the severity of potential impacts to biological resources. Section 4.1.4.4 describes potential impacts to soils from construction, operation and monitoring, and closure.

4.1.4.1 Impacts to Biological Resources and Soils from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities could require additional land disturbance, and current vehicle traffic at the site of the proposed repository would continue. Impacts to biological resources from additional land disturbance could consist of the loss of a small amount of available habitat for terrestrial plant and animal species, including desert tortoises, in widely distributed land cover types and the deaths of a small number of individuals of some terrestrial species. The actual amount of additional land disturbance, if any, is uncertain. DOE expects it to be much less than the quantity of disturbance during site characterization.

The limited habitat loss from additional land disturbance would have little impact on plant and animal populations because habitats similar to those at Yucca Mountain are widespread locally and regionally. Similarly, the deaths of small numbers of individuals of some species, primarily burrowing species of small mammals and reptiles, would have little impact on the regional populations of those species. The animal species at the Yucca Mountain site are generally widespread throughout the Mojave or Great Basin Deserts.

Impacts to desert tortoises from preconstruction testing and performance confirmation would be less than impacts that occurred during site characterization, during which five tortoises have been killed on roads at Yucca Mountain (DIRS 104593-CRWMS M&O 1999, p. 3-12). Habitat loss during the peak of site characterization did not have a detectable effect on the survival, reproduction, behavior, or disease status of desert tortoises living adjacent to construction activities at Yucca Mountain (DIRS 104294-CRWMS M&O 1999, all). Because the desert tortoise is a *threatened species*, it would continue to receive special consideration during land-disturbing activities. DOE would continue to work with the U.S. Fish and Wildlife Service and would implement the terms and conditions required by the Service to minimize impacts to desert tortoises at the site (see Appendix O). Thus, preconstruction testing and performance confirmation would have very little or no impact on the desert tortoise population at Yucca Mountain or along roads traveled to the site.

The potential for soil impacts such as erosion would increase slightly, but erosion control measures, such as dust suppression, would ensure that impacts were very small.

4.1.4.2 Impacts to Biological Resources from Construction, Operation and Monitoring, and Closure

This section describes potential short-term impacts to biological resources at the Yucca Mountain site from construction, operation and monitoring, and closure activities. The primary sources of such impacts would be related to habitat loss or modification during facility construction and operations and to human activities, such as increased traffic, associated with the repository. In addition, this section identifies and evaluates potential impacts to vegetation; wildlife; special status species; and jurisdictional waters of the United States, including wetlands, over the projected life of the project and during each phase of the project.

Routine releases of radioactive materials from the repository would consist mainly of naturally occurring radon-222 and its decay products (see Section 4.1.2 and Appendix G, Section G.2). These releases would result in very small doses to plants and animals around the repository. Estimated doses to humans working and living near the site would be very small (as described in Section 4.1.7). The International

Atomic Energy Agency has concluded that chronic dose rates less than 100 *millirad* per day to plants and animals are unlikely to cause measurable detrimental effects in populations of even the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992, p. 53). Expected dose rates to plants and animals would be much less than 100 millirad per day. Therefore, no detectable impacts to biological resources would occur as a result of normal releases of radioactive materials from the repository, and the following sections do not consider these releases.

Impacts to Vegetation

The construction of surface facilities and the disposition of rock excavated during subsurface construction would remove or alter vegetation. Much of the construction would occur in areas in which site characterization activities had already disturbed the vegetation; however, construction would also occur in undisturbed areas near the previously disturbed areas. Subsurface construction would continue after emplacement operations began, and the disposal of excavated rock would eliminate vegetation in the area covered by the excavated rock pile. The total amount of land cleared of vegetation would vary among the repository operating modes (Table 4-12).

Table 4-12. Land cover types in the land withdrawal area and the amount of each that repository construction and disposal of excavated rock would disturb (square kilometers).[a,b]

Land cover type[c]	Area in Nevada	Land withdrawal area	Area that would be disturbed: Higher-temperature	Area that would be disturbed: Lower- temperature
Blackbrush	9,900	140	0.0	0.0 - 0.2
Creosote-bursage	15,000	300	0.6	0.6 - 0.7
Mojave mixed scrub	5,700	120	2.2	2.4 - 3.6
Sagebrush	67,000	16	0.0	0.0
Salt desert scrub	58,000	20	0.0	0.0
Previously disturbed	NA[d]	4	1.5	1.5
Totals[e]	***NA***	***600***	***4.3***	***4.5 - 6.0***

a. Source: Derived from facility diagrams from DIRS 104523-CRWMS M&O (1999, all) and land cover types maps and vegetation associations (DIRS 102303-CRWMS M&O 1998, all) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. A small area (0.016 square kilometer) of the piñon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
d. NA = not applicable.
e. Totals might differ from sums due to rounding.

Five of the 65 different land cover types (defined primarily by dominant vegetation) identified in the State of Nevada occur in the approximately 600-square-kilometer (230-square-mile) analyzed land withdrawal area around the repository site (Table 4-12). Surface disturbances resulting from repository activities would occur in three of these land cover types and in previously disturbed areas (Table 4-12). Repository construction would disturb less than 1 percent of the withdrawal area, which would be an extremely small percentage of the undisturbed vegetation available in the withdrawal area.

Repository construction, including the disposal of material in the excavated rock pile after the start of emplacement, would occur primarily in previously disturbed areas or areas dominated by creosote-bursage and Mojave mixed scrub.

Repository construction activities in undisturbed vegetation could result in additional areas where colonization by exotic plant species could occur. Exotic species that are currently present on the site (see Section 3.1.5.1.1) would be the most likely *invasive species*. *Native species* could be suppressed in areas colonized by exotic species and there could be an increase in fire fuel load associated with dried annual plant species. Because the undisturbed vegetated area that would be disturbed by construction is small compared to the total undisturbed vegetated area, impacts to native species and the threat of increased fires would also be small.

Studies from 1989 to 1997 indicated that site characterization activities had very small effects on vegetation adjacent to the activities (DIRS 104593-CRWMS M&O 1999, pp. 2-2 through 2-4). Therefore, impacts to vegetation from repository construction probably would occur only as a result of direct disturbance, such as during site clearing. Little or no disturbance of additional vegetation would occur as a result of monitoring and maintenance activities before closure. DOE would reclaim lands no longer needed for repository operation.

Activities associated with the closure of the repository could involve the removal of structures and reclamation of areas cleared of vegetation for the construction of surface facilities. Closure would involve minimal, if any, new disturbance of vegetation. Reclamation activities would enhance the recovery of native vegetation in disturbed areas and reduce colonization by exotic species.

Impacts to Wildlife

The construction of surface facilities and excavated rock disposal would lead to habitat losses for some terrestrial species (Chapter 3, Section 3.1.5); however, habitats similar to those at Yucca Mountain (identified by land cover type) are widespread locally and regionally. In addition to habitat loss, the conversion of undisturbed land to industrial uses associated with the repository would result in the localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles. Birds, carnivores, and ungulates (mule deer or burros) at the repository site would be less likely to be killed during construction because they would be able to move away from areas of human activity.

The construction of new roads, surface facilities, and other infrastructure would lead to fragmentation of previously undisturbed habitat. Nevertheless, DOE anticipates impacts to wildlife populations to be very small because large areas of undisturbed and unfragmented habitat would be available away from disturbed areas.

Animal species present at the repository location are generally widespread throughout the Mojave or Great Basin Deserts and the deaths of some individuals due to repository construction and habitat loss would have little impact on the regional populations of those species. Site characterization activities had no detectable effect on populations of small mammals, side-blotched lizards, and desert tortoises in areas adjacent to the activities (DIRS 104593-CRWMS M&O 1999, pp. 2-4, 2-5, 2-7, and 3-10 to 3-12).

In addition to direct losses due to the construction of surface facilities and excavated rock disposal, individuals of some species would be killed by vehicles traveling to and from the Yucca Mountain site during the construction, operation and monitoring, and closure phases (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). These losses would have a very small effect on populations because species at the site are widespread. No species would be threatened with extinction, either locally or globally.

Noise and ground vibrations generated during repository construction and operations could disturb wildlife and cause some animals to move away from or avoid the source of the noise. Impacts to wildlife from noise and vibration, if any, would decline as the distance from the source of the noise (the repository) increased. Noise levels would drop below the limit of human hearing at a distance of about 6 kilometers (3.7 miles) from the repository (see Section 4.1.9) and no noise-related impacts to wildlife would be likely at that distance. Animals may acclimate to the noise, limiting the area affected by repository-related noise to the immediate vicinity of the source of the noise (heavy equipment, diesel generators, ventilation fans, etc.).

Several animals classified as game species by the State of Nevada (Gambel's quail, chukar, mourning doves, and mule deer) are present in low numbers in the analyzed Yucca Mountain land withdrawal area.

Adverse impacts to these species would be unlikely, and offsite hunting opportunities probably would not decline.

DOE would dispose of industrial wastewater in lined evaporation ponds in the North Portal Operations Area and South Portal Development Area. Wildlife would be attracted to the water in these ponds to take advantage of this otherwise scarce resource. Individuals of some species could benefit from the water, but some animals could become trapped in the ponds, depending on the depth and the slope of the sides. Monitoring at similar lined evaporation ponds on the Nevada Test Site has shown that a wide variety of animal species use the ponds and that DOE could avoid losses of animals by reducing the slopes of the ponds or by providing an earthen ramp at one corner of the lined pond (DIRS 103075-Bechtel 1997, p. 31). Appropriate engineering would minimize potential losses to wildlife.

DOE does not anticipate adverse effects on wildlife that used the nonhazardous, nontoxic wastewater discharged to the evaporation ponds. Industrial wastewater routed to the evaporation pond at the North Portal would be nonhazardous. DOE anticipates that the primary chemical constituents in the water would be sodium and calcium carbonates, with smaller amounts of chlorides, sulfates, and fluorides. Metal constituents could include potassium, zinc, iron, magnesium, and manganese. Wastewater discharged to the South Portal evaporation pond would be nontoxic wastewater derived from dust suppression activities; it would contain small particles of mined rock along with Portland Cement and fine aggregate particles from concrete mix plants. DOE would maintain the pH of the water within a defined range through the addition of acceptable additives. Water quality would be monitored and appropriate measures to protect wildlife would be implemented.

DOE would construct a landfill for construction debris and sanitary solid waste. The landfill could attract scavengers such as coyotes and ravens. Frequent covering of the sanitary waste disposed of in the landfill could minimize use by scavenger species.

After the completion of emplacement, human activities and vehicle traffic would decline, as would impacts of those actions on wildlife, with further declines in activities and impacts after repository closure. Animal species would reoccupy the areas reclaimed during closure activities.

Impacts to Special Status Species

The desert tortoise is the only resident animal species in the analyzed land withdrawal area listed as threatened under the Endangered Species Act of 1973 (16 U.S.C. 1531, *et seq.*). There are no endangered or candidate animal species and no species that are proposed for listing (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). Repository construction would result in the loss of a very small portion of the total amount of desert tortoise habitat at the northern edge of the range of this species in an area where the abundance of desert tortoises is low (DIRS 102869-CRWMS M&O 1997, pp. 6 to 12; DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12).

Based on past experience, DOE anticipates that human activities at the site could directly affect individual desert tortoises. During site characterization activities, 28 tortoises and two tortoise nests were relocated because of threats from construction activities (DIRS 103194-CRWMS M&O 1998, pp. 3 to 17; DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). All but one of the 28 individual relocations and both nest relocations were successful. Five tortoises (including the one unsuccessful relocation) have been killed as a result of site characterization activities; all were killed by vehicles on roads (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). DOE would conduct surveys and would move tortoises that it found; however, based on experience from site characterization, DOE anticipates the deaths of small numbers of individual tortoises from vehicle traffic and construction activities during the repository construction, operation and monitoring, and closure phases.

Although these losses would cause a small decrease in the abundance of desert tortoises in the immediate vicinity of the repository site, they would not affect the long-term survival of the local or regional population of this species. Yucca Mountain is surrounded to the east, south, and west by large tracts of undisturbed tortoise habitat on government property, and desert tortoises are widespread at low densities throughout this region. Habitat loss caused by transportation and other activities during site characterization did not have a detectable effect on the survival, reproduction, behavior, or disease status of desert tortoises living adjacent to construction activities at Yucca Mountain (DIRS 104294-CRWMS M&O 1999, all). In addition, the abundance of ravens at Yucca Mountain did not increase as a result of site characterization activities (DIRS 102236-CRWMS M&O 1998, pp. 9 through 12), and ravens were not an important cause of mortality of small tortoises during that period (DIRS 103195-CRWMS M&O 1998, p. 8).

The U.S. Fish and Wildlife Service has concluded that tortoise populations are depleted for more than a kilometer on either side of heavily used roads (DIRS 102475-Brussard et al. 1994, p. D12). The increase in traffic to Yucca Mountain (see Appendix J, Section J.3.6) would contribute to the continued depression of populations immediately adjacent to U.S. Highway 95, but would not increase the threat to the long-term survival of desert tortoise populations in southern Nevada.

As required by Section 7 of the Endangered Species Act, DOE has completed consultations with the Fish and Wildlife Service concerning the effects of repository construction, operation and monitoring, and closure on the desert tortoise. The U.S. Fish and Wildlife Service has issued a Biological Opinion establishing reasonable and prudent measures and terms and conditions to ensure that implementation of the Proposed Action would not jeopardize the desert tortoise (see Appendix O). The Biological Opinion also contains an incidental take permit. DOE would implement all the measures and terms and conditions of the Biological Opinion to protect the desert tortoise around Yucca Mountain.

The bald eagle and peregrine falcon have been observed once each on the Nevada Test Site and might migrate through the Yucca Mountain region. If present at all, these species would be transient and would not be affected. Bald eagles are classified as threatened under the Endangered Species Act. The State of Nevada classifies the bald eagle and the peregrine falcon as endangered.

Several animal species considered sensitive by the Bureau of Land Management [two bats—the long-legged myotis and fringed myotis—and the western chuckwalla, burrowing owl, and Giuliani's dune scarab beetle; (see Chapter 3, Section 3.1.5)] occur in the analyzed land withdrawal area. Impacts to the bat species would be very small because of their low abundance on the site and broad distribution. Impacts to the Western chuckwalla and burrowing owl would be very small because they are widespread regionally and are not abundant in the land withdrawal area. Giuliani's dune scarab beetle has been reported only in the southern portion of the land withdrawal area, away from any proposed disturbances.

Monitoring and closure activities at the repository would have little impact on desert tortoises, or Bureau of Land Management sensitive species. Over time, vegetation would recover on disturbed sites and indigenous species would return. As the habitat recovered over the long term, desert tortoises and other special status species at the repository site would recolonize areas abandoned by humans.

Impacts to Wetlands

There are no known naturally occurring jurisdictional wetlands (that is, wetlands subject to permitting requirements under Section 404 of the Clean Water Act) on the repository site, so no impacts to such wetlands would occur as a result of repository construction, operation and monitoring, or closure. In addition, repository construction, operation and monitoring, and closure would not affect the four manmade well ponds in the Yucca Mountain region. Repository-related structures could affect as much as 2.8 kilometers (1.7 miles) of ephemeral washes, depending on the size and location of such facilities as the excavated rock storage area. Although no formal delineation has been undertaken, some of these washes might be waters of the United States. After selecting the location of facilities, DOE would conduct a formal delineation, as appropriate, to confirm there are no wetlands at Yucca Mountain; formally delineate waters of the United States near the surface facilities; and, if necessary, develop a plan to avoid when possible, and otherwise minimize, impacts to those waters. If repository activities would affect waters of the United States, DOE would consult with the U.S. Army Corps of Engineers and obtain permit coverage for those impacts. If the activities were not covered under a nationwide permit, DOE would apply to the Corps of Engineers for a regional or individual permit. By implementing the mitigation plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be minimized.

4.1.4.3 Evaluation of Severity of Impacts to Biological Resources

DOE evaluated the magnitude of impacts to biological resources and classified the severity of potential impacts as none, very low, or low, as listed and described in Table 4-13.

Table 4-13. Impacts to biological resources.

Phase or period	Flora	Fauna	Special status species	Wetlands	Overall
Initial construction	Very low/low; removal of vegetation from as much as 4.5 square kilometers[a] in widespread communities	Very low; loss of small amount of habitat and some individuals of some species	Low; loss of small amount of desert tortoise habitat and small number of individual tortoises	None	Very low/low; loss of small amount of widespread but undisturbed habitat and small number of individuals
Construction, operation, and monitoring					
Emplacement and development	Very low/low; disturbance of vegetation in areas adjacent to disturbed areas	Very low; deaths of small number of individuals due to vehicle traffic and human activities	Low; potential deaths of very few individuals due to vehicle traffic	None	Very low new impacts to biological resources
Monitoring and maintenance	Very low; no new disturbance of natural vegetation	Very low; same as for operation, but smaller due to smaller workforce	Very low; same as for operation, but smaller due to smaller workforce	None	Very low; small numbers of individuals of some species killed by vehicles
Closure	Very low; decline in impacts due to reduction in human activity	Very low; decline in number of individuals killed by traffic annually	Very low; decline in number of individuals killed by traffic annually	None	Very low; decline in impacts due to reduction of human activity
Overall rating of impacts	Very low/low	Very low	Very low/low	None	Very low

a. 4.5 square kilometers = 1,100 acres (6.0 square kilometers total area, including areas previously disturbed by site characterization).

4.1.4.4 Impacts to Soils from Construction, Operation and Monitoring, and Closure

This section identifies potential consequences to soils as a result of the Proposed Action. Soil-related issues associated with the Proposed Action include the following:

- Potential consequences of soil loss in disturbed areas, either from erosion or displacement
- *Soil recovery* from disturbances
- Potential for spreading contamination by relocating contaminated soils (if present)

Overall, impacts to soils would be minimal. DOE would use erosion control techniques to minimize erosion. Because soil in disturbed areas would be slow to recover, during the closure phase DOE would revegetate the area that it had not reclaimed after the temporary disturbances following construction.

Soil Loss

Land disturbed at the repository site could, at least for a short period, experience increased erosion. Erosion is a two-step process of (1) breaking away soil particles or small aggregates and (2) transporting those particles or aggregates. Land disturbance that removed vegetation or otherwise broke up the natural surface would expose more small materials to the erosion process, making the soil more susceptible to wind and water erosion. Activities during the construction and operation and monitoring phases would disturb varying amounts of land depending on the operating mode used for the repository. Most of the variation would be due to the emplaced waste being spaced further apart under the lower-temperature operating mode, resulting in more excavated rock being stored on the surface and more ventilation shafts extending from the repository to the surface. A decision to incorporate an aging facility would increase the amount of land disturbed. The highest estimate of newly disturbed land as a result of the Proposed Action is about 4.5 square kilometers (1,100 acres).

Site characterization activities at Yucca Mountain included a reclamation program with a goal to return the disturbed land to a condition similar to its predisturbance state (DIRS 154386-YMP 2001, p. 1). One of the benefits of achieving such a goal would be the minimization of soil erosion. The program included the implementation and evaluation of topsoil stockpiling and stabilization efforts that would enable the use of topsoil removed during excavation in future reclamation activities. The results were encouraging enough to recommend that these practices continue. This action would reduce the construction loss of the most critical type of soil. Fugitive dust control measures including water spraying and chemical treatment would be used as appropriate to minimize wind erosion of the stockpiled topsoil and excavated rock. Based on site characterization experience and the continued topsoil protection and erosion control programs, DOE does not anticipate much soil erosion during any phase of the project.

If the Proposed Action was implemented, program planning developed for site characterization (DIRS 104837-DOE 1989, pp. 2 and 20) specifies that reclamation would occur in all areas disturbed during characterization activities that are not needed for the operation of the repository. As a result, prior land disturbances should represent minimal soil erosion concern during the Proposed Action.

Recovery

Studies performed during the Yucca Mountain site characterization effort (DIRS 104837-DOE 1989, all; DIRS 102188-YMP 1995, all) looked at the ability of the soil ecology to recover after disturbances. These studies and experience at the Nevada Test Site indicate that natural succession on disturbed arid lands would be a very slow process (DIRS 104837-DOE 1989, p. 17; DIRS 102188-YMP 1995, p. 1-5). Left alone, and depending on the type or degree of disturbance and the site-specific environmental conditions, the recovery of

> **SOIL RECOVERY**
>
> The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

predisturbance conditions in this area could take decades or even centuries. With this in mind, soil recovery would be unlikely without reclamation. In general, soil disturbances would remain as areas without vegetation and, with the exception of built-up areas, would have an increased potential for soil erosion throughout the construction and operation and monitoring phases.

Contamination

Based on preconstruction testing and characterization activities that took place in the past (Chapter 3, Section 3.1.5.2), radiological and nonradiological characteristics of the site soils are consistent with the area background. Therefore, there would be no need for restrictions or concerns about contamination migration during construction or as a result of soil erosion. There would be a potential for spills or releases of contaminants to occur under the Proposed Action (as discussed in Section 4.1.3), but DOE would continue to implement a Spill Prevention, Control, and Countermeasures Plan [DIRS 104903-K/PB (1997, all) is an example] to prevent, control, and remediate soil contamination.

4.1.5 IMPACTS TO CULTURAL RESOURCES

This section describes impacts to cultural resources from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of such impacts considered the potential for disrupting or modifying the character of archaeological or historic sites and other cultural resources. The evaluation placed particular emphasis on identifying the potential for impacts to historic sites and other cultural resources important to sustaining and preserving Native American cultures. The region of influence for the analysis included land areas that repository activities would disturb and areas in the analyzed land withdrawal area where impacts could occur.

DOE assessed potential impacts to cultural resources from these activities by (1) identifying project activities that could directly or indirectly affect archaeological, historic, and traditional Native American resources possibly eligible for listing on the *National Register of Historic Places*; (2) identifying the known or likely eligible resources in areas of potential impact; and (3) determining if a project activity would have no effect, no adverse effect, or an adverse effect on potentially eligible resources (36 CFR 800.9). Direct impacts would be those from ground disturbances or activities that would destroy or modify the integrity of a given resource considered eligible for listing on the National Register. Indirect impacts would result from activities that could increase the potential for adverse impacts, either intentional or unintentional (for example, increased human activity near potentially eligible resources could result in illicit collection or inadvertent destruction).

4.1.5.1 Impacts to Cultural Resources from Preconstruction Testing and Performance Confirmation

Land disturbances associated with preconstruction testing and performance confirmation activities could have direct impacts to cultural resources in the Yucca Mountain region of influence (see Chapter 3, Table 3-1). Before activities began, therefore, DOE would identify and evaluate archaeological or cultural resources sites in affected areas for their importance and eligibility for inclusion in the *National Register of Historic Places*. DOE would avoid such sites if practical or, if it was not practical, would conduct a data recovery program of the sites in accordance with applicable regulatory requirements and input from the official tribal contact representatives and document the findings. The artifacts from and knowledge about the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.

4.1.5.2 Impacts to Cultural Resources from Construction, Operation and Monitoring, and Closure

Impacts to archaeological and historic sites could occur during the initial construction phase and the operation and monitoring phase, when ground-disturbing activities would take place. Indirect impacts to archaeological and historic sites could occur during all phases of the Proposed Action.

Archaeological and Historic Resources

Potential impacts to *National Register*-eligible cultural resources from surface facility construction could occur in areas where ground-disturbing activities would take place. Repository development would disturb a maximum of about 4.5 square kilometers (1,100 acres) of previously undisturbed land at the site.

Archaeological investigations conducted in the immediate vicinity of the proposed surface facilities in support of previous and ongoing characterization studies and infrastructure construction have identified about 830 archaeological and historic sites. These investigations have identified resource localities and provided mitigative relief for resources potentially subject to direct impacts (DIRS 104997-CRWMS M&O 1999, Table 2). In addition, ground-disturbing activities associated with potential nearby project actions (for example, upgrades to utility and road rights-of-way, rail access facilities, excavated rock and other onsite storage areas) would occur in areas that had undergone field inventories and evaluations of cultural resources.

Several known archaeological sites in the vicinity of Midway Valley could be affected by ground-disturbing activities associated with the construction of the surface aging facility. An archaeological site occupies much of Midway Valley, including the general location of the proposed surface aging facility. This site was partially mitigated during site characterization activities in 1991 (DIRS 153162-Buck, Amick, and Hartwell 1994, all). In addition, intensive mitigation efforts were conducted at a nearby archaeological site in 1993, yielding nearly 25,000 artifacts (DIRS 153167-Buck et al. 1998, all). Other known archaeological sites occur in the vicinity of the possible location of the solar power generating facility. These sites have not been evaluated beyond field recording, some having been identified more than 20 years ago. One or more of these sites could be affected by construction at the primary location for the solar power generating facility, as well as such features as access roads and transmission cables.

Increases in both surface activities and numbers of workers at the repository site could increase the potential for indirect impacts at archaeological sites near repository surface facilities. Preliminary results from the monitoring of archaeological sites in the vicinity of Yucca Mountain activities since 1991 indicate that human activities and increased access could result in harmful effects, both intentional and inadvertent, to these fragile resources (DIRS 104997-CRWMS M&O 1999, Chapter 1). Indirect impacts are difficult to quantify and control, but they can include loss of surface artifacts due to illicit collection and inadvertent destruction (DIRS 104997-CRWMS M&O 1999, Chapter 1).

Even though there could be some indirect adverse impacts, the overall effect of the repository on the long-term preservation of the archaeological and historic sites in the analyzed land withdrawal area would be beneficial. Cultural resources in the area would be protected from most human intrusion.

Excavation activities at the repository site could unearth additional materials and features in areas that past archaeological surveys have examined only at the surface. Past surveys in the Yucca Mountain area indicated buried cultural materials at some sites with surface artifacts (DIRS 104997-CRWMS M&O 1999, Chapter 1). Thus, excavation activities could unearth previously undetected subsurface features or artifacts. If this happened, work would stop until a cultural resource specialist evaluated the importance of the discovery.

Native American Viewpoints

DOE would continue the existing Native American Interaction Program (see Chapter 3, Section 3.1.6.2) throughout the Proposed Action. This program promotes a government-to-government relationship with associated tribes and organizations. Continuation of this program during the Proposed Action would enhance the protection of archaeological sites and cultural items important to Native Americans.

The Native American view of resource management and preservation is holistic in its definition of “cultural resource,” incorporating all elements of the natural and physical environment in an interrelated context. Moreover, this view includes little or no differentiation between types of impacts (direct versus indirect), but considers all impacts to be adverse and immune to mitigation. Section 4.1.13.4 contains an environmental justice discussion of a Native American viewpoint on the Proposed Action.

Previous studies (DIRS 103465-Stoffle et al. 1990, all; DIRS 102043-AIWS 1998, all) have delineated several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. Construction activities for repository surface facilities would have no direct impacts on these locations. However, because of the general level of importance attributed to these places by Native Americans, and because they are parts of an equally important integrated cultural landscape, Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment (DIRS 102043-AIWS 1998, Chapter 2). In their view, the establishment of the protected area boundary and construction of the repository would continue to restrict the free access of Native American people to these areas. On the other hand, the Consolidated Group of Tribes and Organizations has recognized that past restrictions on public access due to site characterization have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (DIRS 102043-AIWS 1998, Chapter 2).

The potential for indirect impacts from construction activities and more workers in the area would increase, particularly to the physical evidence of past use of the cultural landscape (artifacts, cultural features, archaeological sites, etc.) important to Native American people. DOE would continue to provide training to workers to minimize the potential for indirect impacts.

Eventual closure of the repository would have the beneficial effect of returning much of the disturbed landscape to a natural setting. Some additional impacts could occur to resources or areas important to Native Americans if changes in land status or management that occurred after closure led to increased access by the public. The presence of a permanently entombed repository would represent an intrusion into what Native Americans consider an important cultural and spiritual place. Long-term monitoring features or activities would continue to affect these cultural viewpoints.

4.1.6 SOCIOECONOMIC IMPACTS

This section describes potential socioeconomic impacts from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. Evaluations of the socioeconomic environment in communities near the proposed repository site considered changes to employment, economic measures, population, housing, and some public services. The evaluation used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions and to estimate economic and population changes caused by the Proposed Action. The potential for changes in the socioeconomic environment would be greatest in the Yucca Mountain region of influence where most of the repository workers would live. As discussed in Chapter 3, Section 3.1.7, this region of influence consists of Clark, Lincoln, and Nye Counties in southern Nevada.

DOE examined the maximum potential employment levels that would be required to implement the range of operating modes. The analysis did not project baseline population or employment in the region of influence beyond 2035 because of the speculative nature of such a forecast.

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The discussion in this section of changes to population, employment, Gross Regional Product, real disposable income, and expenditures by the State of Nevada and local governments resulting from the Proposed Action are the deviations from a projected baseline for each parameter. This baseline utilizes data DOE received from the State and local governments. Chapter 3, Section 3.1.7 discusses this baseline.

DOE has considered suggestions made in public comments that the EIS include analysis of possible impacts of perceptions associated with the proposed repository. DOE has determined that it could not quantify any potential impacts resulting from such perceptions and that further research would be unlikely to make quantification possible. From a qualitative standpoint, adverse impacts from perceptions of the repository would be unlikely, absent a large accident or a continuing series of smaller accidents. Section 2.5.4 discusses the reasons for DOE's determination.

4.1.6.1 Socioeconomic Impacts from Preconstruction Testing and Performance Confirmation

The level of employment for preconstruction testing and performance confirmation activities would be similar to or less than the current level of employment for site characterization, as described in Chapter 3, Section 3.1.7. Because population and employment changes between ongoing site characterization activities and future performance confirmation activities would be minimal, there would be no meaningful impacts to housing or public services, including impacts to schools.

4.1.6.2 Socioeconomic Impacts from Construction, Operation and Monitoring, and Closure

4.1.6.2.1 *Impacts to Employment*

> **TERMS RELATED TO EMPLOYMENT**
>
> **Direct Employment:** Jobs expressly associated with project activity.
>
> **Indirect Employment:** Jobs created as a result of expenditures by directly employed project workers (for example, restaurant workers or child care providers) or jobs created by the project-related purchase of goods and services (for example, sales manager of a concrete supply store).
>
> **Composite Employment:** Sum of direct and indirect jobs.

In 2006, the peak year of employment during the initial construction phase, about 1,900 additional workers would also be employed on the Yucca Mountain Repository Project. Figure 4-2 shows composite (direct and indirect) employment changes caused by construction activities, by place of residence during this phase. Incremental employment increases during the construction phase attributable to the repository would peak in 2006 with the addition of about 3,400 workers to the region of influence. This would increase overall employment in the region of influence from the projected baseline (employment without the repository project) of approximately 942,000 jobs to slightly less than 945,000 positions, a change of approximately 0.36 percent. Table 4-14 summarizes repository peak year employment during the initial construction period by place of residence in selected communities. Table 4-15 lists the expected residential distribution of directly employed construction workers over the primary construction phase. These tables do not list Lincoln County because, historically, very few Yucca Mountain Project workers have resided in the County. DOE expects that few, if any, repository employees would live in Lincoln County given the long commute.

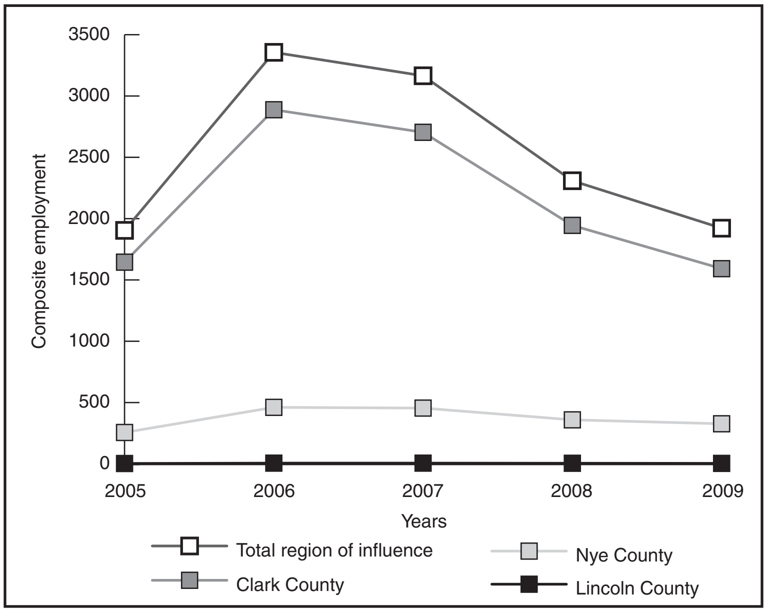

Figure 4-2. Increases in regional composite employment by place of residence during construction phase.

Table 4-14. Expected peak year (2006) increase in construction employment by place of residence in selected communities in Nye and Clark Counties.[a,b,c]

Location	Direct jobs[d]	Indirect jobs[d]	Total jobs[d]
Clark County			
Indian Springs	60	40	100
Rest of Clark County	1,440	1,360	2,800
Clark subtotals	*1,500*	*1,400*	*2,900*
Nye County			
Amargosa Valley	20	10	30
Beatty	3	2	5
Pahrump area	340	90	430
Nye subtotals	*360*	*100*	*460*
Totals[e]	***1,860***	***1,500***	***3,360***

a. Employment and population impacts distributed using residential patterns of Nevada Test Site and Yucca Mountain employees from DOE (DIRS 155987-DOE 2001, all).
b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County; includes approximately 5 indirect jobs in Lincoln County.
c. Employment in 2006 does not include approximately 220 current workers.
d. Numbers have been rounded to the nearest 10.
e. Totals might not equal sums of values due to rounding.

Table 4-15. Repository direct employment during construction phase by expected county of residence: 2005 to 2009.[a,b,c,d]

County	2005	2006	2007	2008	2009
Clark	1,000	1,660	1,660	1,360	1,300
Nye	240	410	400	330	320
Totals[e]	**1,240**	**2,070**	**2,060**	**1,700**	**1,610**

a. Sources: DIRS 104508-CRWMS M&O (1999, Section 6); DIRS 104523-CRWMS M&O (1999, Section 6).
b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County.
c. Includes approximately 220 current workers.
d. Numbers are rounded to the nearest 10.
e. Totals might not equal sums of values due to rounding.

Training of operational personnel would begin in 2009. In 2010, direct operational employment would start to increase. Direct operational peak employment would occur in 2012 (with about 2,150 workers). Employment after 2012 would be essentially stable with an average annual workforce of about 1,900 through the year 2033 when operations would be completed.

At the start of the monitoring period, a workforce of up to 1,160 workers would be involved in decontamination of surface facilities for a period of approximately 3 years. The impact to employment from the decontamination activities would be less than 1 percent of the estimated baseline. Figure 4-3 reflects this short-term increase. After decontamination was completed, direct employment would decrease substantially for the remainder of the monitoring period.

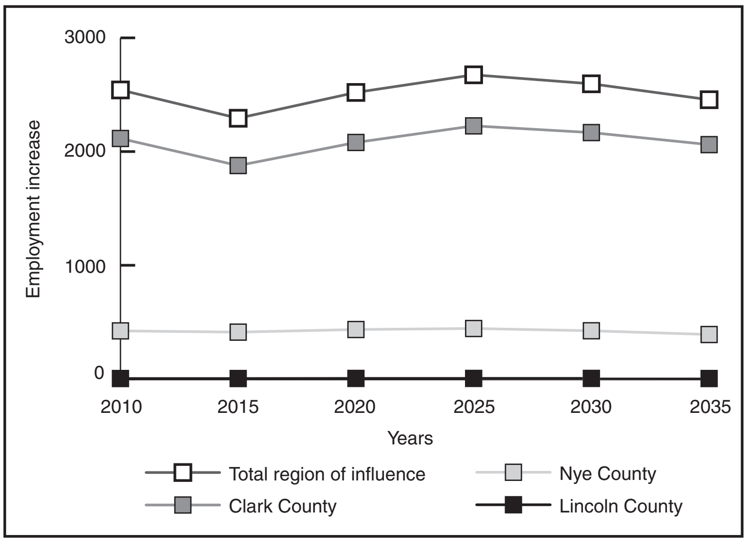

Figure 4-3. Changes in regional employment from operations period and decontamination activities.

Table 4-16 lists the expected residential distribution of repository workers in the peak year of employment (2012) during the operations period. The table also lists the estimated number of indirect jobs created in these communities during 2012. The direct and indirect employment in the region of influence would peak with the addition of approximately 2,700 workers. This would result in an incremental increase of employment from the estimated baseline of about 1,029,000 jobs to about 1,031,000 jobs, a change of less than 0.26 percent from the estimated employment baseline.

Table 4-17 summarizes direct repository employment through the first 24 years of the operation and monitoring phase by county of residence. This table does not list Lincoln County because, historically, so few workers have resided in the County. Figure 4-3 shows the direct and indirect regional employment differences between the bounding employment case for the lower-temperature operating mode with aging and the estimated baseline.

Monitoring and maintenance activities would start with the first emplacement of waste package and would continue through repository closure. DOE estimates that a workforce of approximately 120 workers would be needed to monitor and maintain the repository. Given the expected economic growth in the region of influence, the region could readily absorb declines in repository employment.

To bound this study, the socioeconomic analysis assumes that closure would begin 100 years after the start (and 76 years after the completion) of emplacement activities. The lower-temperature operating mode would require a longer monitoring period, ranging from 125 to 300 years. Therefore, this analysis evaluated potential impacts of a closure of the repository in the lower-temperature mode after as many as

Table 4-16. Expected peak year (2012) increases in operations period employment in selected communities in Clark and Nye Counties.[a]

Location	Direct jobs[b]	Indirect jobs	Total jobs
Clark County			
Indian Springs	70	20	90
Rest of Clark County	1,490	620	2,110
Clark subtotals	*1,560*	*640*	*2,200*
Nye County			
Amargosa Valley	20	10	30
Beatty	3	0	3
Pahrump area	350	70	420
Nye subtotals	*380*	*80*	*460*
Totals[c]	***1,940***	***720***[d]	***2,660***

a. Numbers have been rounded to the nearest 10.
b. Employment in 2012 does not include approximately 220 current workers.
c. Totals might not equal sums of values due to rounding.
d. Includes 4 indirect workers in Lincoln County.

Table 4-17. Repository direct employment during operations period and decontamination activities by county of residence: 2010 to 2035.[a,b,c]

County	2010	2015	2020	2025	2030	2035[d]
Clark total	1,630	1,600	1,650	1,640	1,560	1,420
Nye total	400	390	400	400	380	350
Totals[c]	***2,030***	***1,990***	***2,050***	***2,040***	***1,940***	***1,770***

a. Includes approximately 220 current workers.
b. Numbers have been rounded to the nearest 10.
c. Totals might not equal sums of values due to rounding.
d. Year 2035 shows the short-term (3-year) impact of decontamination activities.

324 years of operation and monitoring. Employment would be far less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate employment changes and economic measures of more than one-half of 1 percent. There probably would be no perceptible repository-induced changes to baseline employment in the region of influence. Regional impacts to socioeconomic parameters during the closure phase would be small.

4.1.6.2.2 *Impacts to Population*

From 2010 through 2035 the projected regional population will grow from about 1.9 million residents to approximately 2.8 million. The peak year population contribution attributable to the repository would be approximately 6,200 people, or approximately 0.24 percent of the region of influence's estimated population baseline of 2.6 million people in 2030. As a result, the Yucca Mountain Repository Project would have only small effects on the population growth in the region of influence. Figure 4-4 shows the projected population increase resulting from the repository project.

Table 4-18 lists estimated incremental population increases that would occur as a result of repository activities in Clark and Nye Counties based on historic Nevada Test Site residential distribution patterns. As mentioned above, repository workers would be unlikely to reside in Lincoln County. The incremental peak population increase in Clark County would be less than 0.21 percent.

Population growth associated with the repository would be more evident in Nye County. The County's population increase would be approximately 1.4 percent of the projected population of 77,000, for the County in 2030, the peak year for potential repository population impacts.

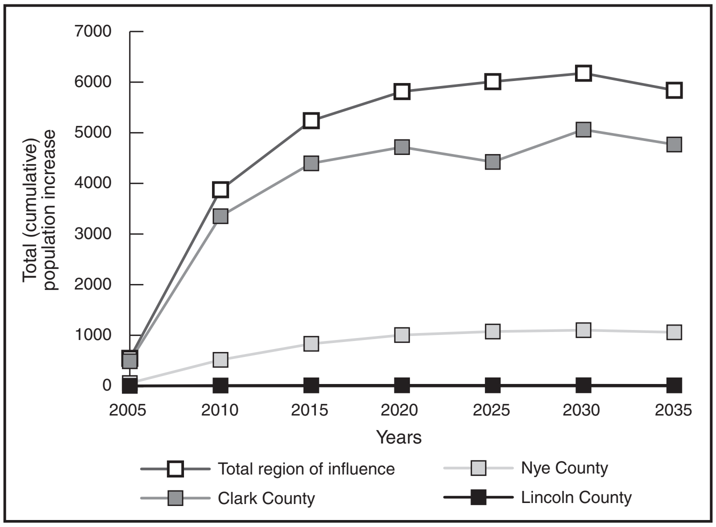

Figure 4-4. Regional population increases from construction and operations: 2000 to 2035.

Table 4-18. Maximum expected population increase from Proposed Action (2030).[a,b]

Location	Population increase
Clark County	
Indian Springs	180
Rest of Clark County	4,880
Clark total	***5,060***
Nye County	
Amargosa Valley	80
Beatty	10
Pahrump	1,000
Nye total	***1,100***

a. Numbers have been rounded to the nearest 10.
b. Totals might not equal sums of values due to rounding.

4.1.6.2.3 *Impacts to Economic Measures*

Table 4-19 lists estimated changes in economic measures that would result from repository activities during the construction phase (values are expressed in 2001 dollars). Increases in real disposable income within the region of influence would peak in 2007 with an increase of about $110 million, while increases in Gross Regional Product would peak in 2006 at about $160 million. Regional expenditures by State and local governments would peak at $11 million in 2009. Economic measures for the region of influence would increase by less than one-third of 1 percent over the projected baseline (estimated economic measures without the repository project).

Table 4-20 lists the changes in economic measures that would result from the repository project duringthe operations period. Increases in Gross Regional Product would peak in 2029 at about $125 million. Increases in real disposable income would peak in 2029 at $149 million. Increases in regional expenditures by State and local governments under the maximum employment case would peak in 2030 at about $22 million. Economic measures for the region of influence would increase by less than 0.5 percent over the projected baseline.

GROSS REGIONAL PRODUCT

The value of all final goods and services produced in the region of influence.

4.1.6.2.4 Impacts to Housing

Given the size of the regional employment, the number of workers in-migrating to work on the repository would be relatively small. Because the inmigration would be small, the increased demand for housing would also be small.

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Table 4-19. Increases in economic measures within the region of influence from repository construction: 2005 to 2009 (millions of dollars).[a]

Jurisdiction	2005	2006	2007	2008	2009
Clark County					
Disposable income	54	100	103	85	77
Gross Regional Product	80	142	136	100	73
State and local government expenditures	1.5	4.8	7.6	9.1	9.9
Nye County					
Disposable income	3.7	6.7	6.8	5.7	5.9
Gross Regional Product	10	19	18	15	12
State and local government expenditures	0.2	0.5	0.9	1	1.3
Lincoln County					
Disposable income	0.1	0.3	0.3	0.2	0.2
Gross Regional Product	0.1	0.2	0.2	0.2	0.1
State and local government expenditures	0	0	0.1	0.1	0.1
Total region of influence[b]					
Disposable income	58	108	110	90	83
Gross Regional Product	90	160	155	115	85
State and local government expenditures	1.7	5.3	8.5	10	11

a. Numbers are expressed in 2001 dollars.
b. Totals might differ from sums of values due to rounding.

Table 4-20. Increases in economic measures within the region of influence from emplacement and development activities: 2010 to 2033 (millions of dollars).[a]

Jurisdiction	2010	2015	2020	2025	2030	2033
Clark County						
Disposable income	97	104	119	129	133	110
Gross Regional Product	90	82	96	106	105	69
State and local government expenditures	11	15	16.7	18	13	17
Nye County						
Disposable income	8.2	11	13	14	15	14
Gross Regional Product	15	15	16	17	17	12
State and local government expenditures	1.6	2.6	3.2	3.5	3.7	3.6
Lincoln County						
Disposable income	0.3	0.3	0.3	0.4	0.4	0.3
Gross Regional Product	0.2	0.2	0.2	0.2	0.2	0.2
State and local government expenditures	0.1	0.1	0.1	0.1	0.1	0.1
Total region of influence[b]						
Disposable income	106	115	132	144	149	124
Gross Regional Product	104	97	113	123	122	81
State and local government expenditures	12	18	20	21	22	21

a. Numbers are expressed in 2001 dollars.
b. Totals might differ from sums of values due to rounding.

The impact to housing would be minimal because (a) the expected increase in population is so small, (b) the demand is expected to be concentrated in a metropolitan area (Clark County), (c) there are no municipal or state growth control measures that limit housing development, and (d) the region of influence has an adequate supply of undeveloped land to meet expected future demands. Southern Nye County, particularly Pahrump, would experience some demand for housing. In Lincoln County, little or no demand for housing resulting from repository activities would be likely, so housing availability would not be an issue.

During the 1990s and early 21st century, the Bureau of Land Management has conducted land exchanges in Nevada. These exchanges have typically involved a trade of environmentally sensitive land outside Clark County for Bureau land in the County. The land in Clark County moves to the private sector for sale to land developers, particularly developers of large master-planned, densely occupied communities. The land swap policy has helped to accommodate population growth in the greater Las Vegas area.

4.1.6.2.5 Impacts to Public Services

Repository-generated impacts to public services from population changes in the region of influence would be small. Population changes in the region from the maximum repository-related employment case would be a small fraction of the anticipated population growth in the region. Even without the addition of repository jobs, the annual regional growth rate would increase by an estimated 2 to 4 percent, minimizing a possible need to alter plans already in place to meet projected growth.

As mentioned above, the majority of inmigrating workers would likely live in the many communities of Clark County, thereby dispersing the increased demand for public services, including schools. Southern Nye County, particularly Pahrump, also would experience an increased demand for public services. However, because the changes in population (about 1,100 residents in the peak year) would occur steadily over a long period, the County would be able to absorb increased demands in education, law enforcement, and fire protection. Repository-generated impacts to public services would be unlikely in Lincoln County.

4.1.6.3 Summary of Socioeconomic Impacts

The potential socioeconomic impacts associated with repository activities are summarized in this section. For all five socioeconomic parameters evaluated over construction, operations, and decontamination activities, the impacts would be very small, less than 1 percent of the baselines for the region of influence. The construction phase would experience greater impacts for employment, Gross Regional Product, and real disposable income. The operations and decontamination activities would cause the greater impact from increases in population and government spending.

The lower-temperature operating mode and the higher-temperature operating mode would have similar potential impacts. Composite employment, which includes workers directly associated with the construction activity and other indirect workers (food service providers and auto mechanics for example), would peak in 2006. The increase of 3,400 workers represents a 0.36 percent increase to the expected baseline. Gross Regional Product would also peak in 2006 as various goods and services associated with the construction activities were consumed. The expected increase in Gross Regional Product for 2006 is about $160 million, (all values for economic parameters are expressed in 2001 dollars) or 0.31 percent of the baseline. Peak years for the other socioeconomic impacts would be delayed until the operations period. Population increases caused by the increased employment opportunities would peak in 2030, at about 6,200 or less than 0.25 of a percent of the baseline for the year. Government spending would peak in 2030 at $22 million or 0.22 percent of the baseline. Disposable income would also be highest during the operations period, peaking in 2029 at $149 million, or 0.23 percent of the baseline. Impacts during the subsequent decontamination activities, monitoring period, and closure phase would be similar to or smaller than the impacts summarized above.

4.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY IMPACTS

This section describes potential health and safety impacts to workers (occupational impacts) and to members of the public from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. The analysis estimated health and safety impacts separately for involved workers and noninvolved workers for each repository phase. Involved workers are craft and operations personnel who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, aging, and emplacement of spent nuclear fuel and high-level radioactive waste materials; maintenance of the solar power facility; monitoring of the condition and performance of the waste packages; and eventual closure of the repository. Noninvolved workers are managerial, technical, supervisory, and administrative personnel who would not be directly involved in the above activities. This section describes impacts from the receipt of uncanistered spent nuclear fuel. Impacts for canistered fuel would be smaller, as reported in Appendix F, Section F.2.

The types of potential health and safety impacts to repository workers include those from industrial hazards common to the workplace, those from exposure to naturally occurring and manmade radiation and radioactive materials present in the workplace, and those from exposure to naturally occurring nonradioactive airborne hazardous material. Members of the public could be exposed to airborne releases of naturally occurring and manmade radionuclides and naturally occurring hazardous materials. Estimates of human health impacts to members of the public are based on information presented in Section 4.1.2.

Appendix F describes the methodology, data, and data sources used for the calculations of health and safety impacts to workers and supporting detailed results. It also contains a human health impacts primer.

4.1.7.1 Impacts to Occupational and Public Health and Safety from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would be similar to the activities performed during Yucca Mountain site characterization. Their purpose would be to ensure that systems, operations, and materials were functioning as predicted. These activities could include the construction of surface facilities to support performance confirmation, excavation of exploratory tunnels, and testing and monitoring activities in the drifts. Chapter 3 describes site characterization activities and the resulting affected environment.

Potential health and safety impacts that could occur during preconstruction testing and performance confirmation activities include those common to an industrial work setting, radiological impacts to the public and workers from exposure to radon-222 and its decay products, external radiation exposure of workers in the subsurface environment, and the potential for exposure to naturally occurring hazardous materials generated by excavation activities. Section 4.1.7.2 contains additional information on these potential exposure pathways. No spent nuclear fuel and high-level radioactive waste would be present during preconstruction testing and performance confirmation activities, so radiation exposure of workers from this source would not occur.

Impacts are likely to be very small during preconstruction testing and performance confirmation activities. Incremental health and safety impacts to workers for the performance confirmation period would be less than 2 percent of those estimated for the construction, operation and monitoring, and closure phases, based on comparisons of worker activities and the number of worker-years between site characterization (DIRS 104957-DOE 1994, all) and repository activities (see Appendix F). Potential radiological impacts to members of the public would be less than those estimated for the construction phase (Section 4.1.7.2). The probability of latent cancer fatality in the offsite maximally exposed individual would be about 0.0000002. No latent cancer fatalities (less than 0.004) would be likely in the potentially exposed population.

4.1.7.2 Impacts to Occupational and Public Health and Safety from Initial Construction

This section describes estimates of health and safety impacts to repository workers and members of the public for the 5-year initial construction phase. During this phase, DOE would build the surface facilities, excavate the main drifts, and excavate enough emplacement drifts to support initial emplacement activities. Potential health and safety impacts to workers would occur from industrial hazards, exposure to naturally occurring radionuclides, and exposure to naturally occurring cristobalite and erionite in the rock at the Yucca Mountain site. Potential health impacts to members of the public would be from exposure to airborne releases of naturally occurring radionuclides and hazardous materials.

4.1.7.2.1 *Occupational Health and Safety Impacts*

Industrial Hazards. The analysis estimated health and safety impacts to workers from hazards common to the industrial setting in which they would be working using statistics for similar kinds of operations in the DOE complex and estimates of the total number of full-time equivalent worker years that would be involved in the activity. The statistics that the analysis used are from the DOE Computerized Accident/ Incident Reporting and Recordkeeping System (DIRS 147938-DOE 1999, all). These statistics reflect recent DOE experience for these types of activities. Appendix F, Section F.2.2.2, contains more information on the selection of impact statistics.

Estimates of impacts were based on the number of full-time worker years during the construction phase for the repository operating modes. Table 4-21 lists the estimated impacts to workers from industrial hazards for the repository construction phase. The table lists impacts for three types of industrial safety impacts; total recordable cases of injuries and illnesses that are work-related, total lost workday cases, and fatalities (see the discussion in Appendix F, Section F.2.2).

Table 4-21. Impacts to workers from industrial hazards during initial construction phase.[a,b]

	Operating mode	
Worker group and impact category	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	340	340 - 370
Lost workday cases	160	160 - 180
Fatalities	0.16	0.16 - 0.18
Noninvolved workers		
Total recordable cases	55	55 - 61
Lost workday cases	27	27 - 30
Fatalities	0.048	0.048 - 0.054
All workers (totals)[c]		
Total recordable cases	400	400 - 430
Lost workday cases	190	190 - 210
Fatalities	0.21	0.21 - 0.23

a. Source: Appendix F, Table F-12. Numbers are rounded to two significant figures.
b. The analysis assumed that the construction phase would last 44 months for surface facility construction and 60 months for subsurface construction activities.
c. Totals might differ from sums of values due to rounding.

No worker fatalities would be expected during construction for any of the operating modes. For the higher-temperature operating mode, the estimated fatalities are 0.21. The range for the lower-temperature operating mode is 0.21 to 0.23 fatality.

Naturally Occurring Hazardous Materials. Two types of naturally occurring hazardous materials could be encountered by workers at the Yucca Mountain site—cristobalite, a form of crystalline silica (silicon dioxide, SiO_2), and erionite, a naturally occurring zeolite. Both are present in the subsurface rock at Yucca Mountain and have the potential to become airborne during repository excavation and activities involving excavated rock and would be released during tunneling operations. It could also be released with dust from the excavated rock pile. Erionite is a natural zeolite that occurs in the rock layers below the proposed repository level (see Chapter 3, Section 3.1.3). It might also occur in rock layers above the repository level but activities to date have not found it in those layers. Erionite could become a hazard during vertical boring operations if the operations passed through a rock layer containing erionite (which would be unlikely), and during excavation for access to the lower block. Additional information on the potential hazards of these naturally-occurring materials is found in Appendix F, Section F.1.2.

Cristobalite is present in the welded tuff at the repository level and would become airborne in the repository environment during excavation and rock moving activities. The welded tuff has an average cristobalite content of between 18 and 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81).

DOE would use engineering controls during subsurface work to control exposures of workers to silica dust. Water would be applied during excavation activities to wet both the rock face and the broken rock to minimize airborne dust levels. Wet or dry dust scrubbers would capture dust that the water sprays did not suppress. The fresh air intake and the exhaust air streams would be separated to prevent increased dust concentrations in the drift atmosphere from recirculation. In addition, the ventilation system would be designed and operated to control ambient air velocities to minimize dust resuspension. DOE would monitor the working environment to ensure that workers were not exposed to dust concentrations higher than the applicable limits for cristobalite. If engineering controls were unable to maintain dust concentrations below the limits, administrative controls such as access restrictions or respiratory protection would be used until the engineering controls could establish acceptable conditions. Similar controls would be applied, if required, for surface workers. DOE expects that exposure of workers to silica dust would be below the applicable limits and potential impacts to subsurface and surface workers would be very small.

DOE does not expect to encounter erionite layers either during vertical boring operations (which would be through rock layers above known erionite layers) or during excavation to provide access to the lower block and offset areas. Access excavation would be planned to avoid any identified layers of erionite (DIRS 104532-McKenzie 1998, all). If erionite was encountered during excavation for access to the lower block or during vertical boring operations, the engineering controls described above for cristobalite would be instituted and, if necessary, administrative controls would be used until acceptable conditions were reestablished.

Radiological Health Impacts. Spent nuclear fuel and high-level radioactive waste would not be present at the repository site during the construction phase and so would not contribute to radiological impacts. Potential radiological health impacts to involved and noninvolved workers in subsurface facilities during the initial construction phase would be from two sources: inhalation of naturally occurring radon-222 and its decay products following emanation of the radon from the surrounding rock, and external radiation dose from naturally occurring radionuclides in the drift walls, principally potassium-40 and radionuclides in the uranium decay series (DIRS 104544-CRWMS M&O 1999, Sections 4 and 5). Radon-222 is a noble gas of the uranium-238 decay series. Because it is a noble gas, radon emanates from the rock into the drifts, where elevated concentrations of radon-222 and its decay products could occur in the repository atmosphere (see Chapter 3, Section 3.1.8.2). Workers in surface facilities and members of the public would also be exposed to naturally occurring radon-222 and decay products as these radionuclides would be released from the subsurface in exhaust ventilation air. Section 4.1.2.2.2 provides more detailed discussion of these airborne release exposures.

Measurements in the Exploratory Studies Facility indicated an underground ambient external dose rate from radionuclides in the drift walls of about 50 millirem per work year of 2,000 hours underground. This is slightly higher than the dose rate from the cosmic and cosmogenic components of natural background radiation on the surface of about 40 millirem per year in the Amargosa Valley region (see Section 3.1.8.2). This analysis considers the underground ambient external radiation dose to be part of the involved worker occupational dose.

Table 4-22 lists estimated potential doses and radiological health impacts for the construction phase to involved workers, noninvolved workers, and the total for all workers. It includes estimated doses and

Table 4-22. Radiation dose and radiological health impacts to workers during the initial construction phase.[a,b,c]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker		
Dose, rem		
Involved	1.3	1.3
Noninvolved	0.33	0.33
Probability of latent cancer fatality		
Involved	0.00052	0.00052
Noninvolved	0.00013	0.00013
Worker population		
Collective dose (person-rem)		
Involved	680	680
Noninvolved	37	37
Total[d]	720	720
Number of latent cancer fatalities		
Involved	0.27	0.27
Noninvolved	0.015	0.015
Total[d]	**0.29**	**0.29**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-11.
c. Only subsurface workers have potential for measurable radiation dose (from natural sources) during the initial construction phase.
d. Totals might differ from sums of values due to rounding.

radiological health impacts for the maximally exposed involved worker and for the involved worker population; radiological health impacts for the maximally exposed noninvolved worker and for the noninvolved worker population; and the estimated collective dose and radiological health impacts for the combined population of workers. Estimated doses were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0004 latent cancer fatality per rem (see Appendix F, Section F.1.1.5). Radiological health impacts for maximally exposed individuals are presented as the increase in the probability of a latent cancer fatality resulting from the radiation dose received. Radiological health impacts for exposed populations are presented as the number of latent cancer fatalities estimated to result from the collective radiation dose received.

During the initial construction phase the only source of radiation would be from naturally occurring radionuclides in the subsurface, so radiological health impacts to the surface facility workforce would be much lower than those to the subsurface facility workforce. Values presented in Table 4-22 are those for subsurface workers (see Appendix F, Table F-11).

The estimated increase in the number of latent cancer fatalities for workers would be low (about 0.3); the estimated increase in the likelihood that an individual worker would die from a latent cancer fatality would also be small (about 0.0005).

4.1.7.2.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Section 4.1.2.2.1 presents estimated annual average concentrations of cristobalite at the *site boundary* where members of the public could be exposed during the construction phase. The analysis estimated concentrations of about 0.02 microgram per cubic meter for the operating modes, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public during the construction phase would come from exposure to airborne releases of naturally occurring radon-222 and its decay products in the subsurface exhaust ventilation air. Estimates of radiation doses for the offsite maximally exposed individual and the potentially exposed population are presented in Section 4.1.2.2.2. The offsite maximally exposed individual is a hypothetical member of the public at a point on the land withdrawal boundary that would receive the highest radiation dose and resultant radiological health impact. This location would be at the southern boundary of the land withdrawal area. The exposed population is that within 80 kilometers (50 miles) of the repository (see Section 3.1.8). Estimated doses to members of the public were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0005 latent cancer fatality per rem for members of the public (see Appendix F, Section F.1.1.5).

Table 4-23 lists the estimated doses and radiological health impacts to members of the public from the 5-year initial construction phase. The radiological health impacts to the public from repository construction would be very small (with 0.02 latent cancer fatality or less estimated for all of the operating modes). The estimated individual risk of contracting a latent cancer fatality for the maximally exposed individual would be 0.000001 or less over the 5-year phase.

Table 4-23. Radiation doses and radiological health impacts to the public during the initial construction phase.[a,b,c]

	Operating mode			
	Entire phase		Maximum annual	
Dose and health impact	Higher-temperature	Lower-temperature	Higher - temperature	Lower-temperature
Maximally exposed individual[d]				
Dose (millirem)	1.7	1.7 - 2.0	0.43	0.43 - 0.53
Latent cancer fatality probability	8.5×10^{-7}	$0.85 - 1.0 \times 10^{-6}$	2.1×10^{-7}	$2.1 - 2.6 \times 10^{-7}$
Exposed 80-km population[e]				
Collective dose (person-rem)	33	33 - 40	8.4	8.4 - 10
Number of latent cancer fatality	0.017	0.017 - 0.020	0.0042	0.0042 - 0.0052

a. Numbers are rounded to two significant figures.
b. Source: Table 4-2.
c. All of the dose and impact are from naturally occurring radon-222 and decay products.
d. Located at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

4.1.7.3 Occupational and Public Health and Safety Impacts from Operation and Monitoring

This section describes possible health and safety impacts to workers and members of the public for the operation and monitoring phase. This phase has two main components: the operations period (including continuing subsurface development) and the monitoring period. The overall phase length would range from 100 years for the higher-temperature operating mode up to 324 years for the lower-temperature operating mode. Impacts of the operations period and the monitoring period are described below.

4.1.7.3.1 *Operations Period – Handling, Emplacement, and Continuing Development*

This period would consist of a 24-year period for operations, including the receipt, handling, packaging, possible aging, and emplacement of spent nuclear fuel and high-level radioactive waste. There would be a concurrent (except for the last two years) 22-year period for continued construction (development) of underground repository features, including access drifts, emplacement drifts, shafts, and so on. Where aging of commercial spent nuclear fuel could occur under the lower temperature operating mode an additional 26 years of emplacement and handling would be needed, for a total operations period length of 50 years.

4.1.7.3.1.1 Occupational Impacts

Industrial Hazards. Table 4-24 summarizes health and safety impacts from common industrial hazards for the operations period. Impacts were estimated separately for surface operations, subsurface emplacement operations, and subsurface drift development operations, then were summed to develop these results.

Table 4-24. Impacts to workers from industrial hazards during the operations period.[a]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	1,200	1,200 - 1,700
Lost work day cases	590	620 - 840
Fatalities	0.90	0.91 - 1.4
Noninvolved workers		
Total recordable cases	300	310 - 470
Lost workday cases	150	150 - 230
Fatalities	0.31	0.31 - 0.45
All workers (totals)[b]		
Total recordable cases	1,500	1,500 - 2,200
Lost workday cases	740	770 - 1,100
Fatalities	1.2	1.2 - 1.9

a. Values taken from Appendix F, Table F-22.
b. Totals might differ from sums of values due to rounding.

About 1.2 fatalities were estimated for the higher-temperature operating mode, with a range of 1.2 to 1.9 fatalities estimated for the lower-temperature operating mode. The highest estimates would be where aging would be used (longer operations period, more worker-years) with maximum spacing of the waste packages, which results in the largest repository and thus more excavation.

Naturally Occurring Hazardous Material. As discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures to control and minimize impacts to workers from releases of cristobalite and erionite during the operations period. Controls would be necessary mainly for continuing development activities underground but also for activities associated with the excavated rock pile. As for the construction phase, impacts would be expected to be very small.

Radiological Health Impacts. Occupational radiological health impacts during the operations period would be a combination of impacts to surface workers during handling operations, and impacts to subsurface workers during development and emplacement operations. These impacts are presented in Table 4-25.

The estimated radiological health impacts to the worker population for the 24 or 50-year operations period would range from 3.1 to 4.8 latent cancer fatalities. Estimated radiological health impacts to the maximally exposed individual would range from 15 to 30 rem, with a corresponding probability of latent cancer fatality ranging from 0.0060 to 0.012. The principal contributors to radiological health impacts would be surface facility operations, which would involve the receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for emplacement and subsurface monitoring activities.

Table 4-25. Radiation dose and radiological health impacts to workers during the operations period.[a,b]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Maximally exposed worker		
Dose, rem		
Involved	15	15 - 30
Noninvolved	1.5	1.5 - 1.8
Probability of latent cancer fatality		
Involved	0.0060	0.0060 - 0.012
Noninvolved	0.00060	0.00060 - 0.00072
Worker population		
Collective dose (person-rem)		
Involved	7,500	7,600 - 12,000
Noninvolved	150	160 - 170
Total[c]	**7,700**	**7,800 - 12,000**
Number of latent cancer fatalities		
Involved	3.0	3.0 - 4.8
Noninvolved	0.060	0.064 - 0.068
Total[c]	**3.1**	**3.1 - 4.8**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-23.
c. Totals might differ from sums of values due to rounding.

DOE would consider the inspection, testing, or retrieval of a waste package that had already been emplaced to be an off-normal condition of routine operations that it has already considered (see Chapter 2, Section 2.1.2.2.3). Any such operation would be carried out under the repository radiation protection program, and worker dose limits would apply. Therefore, any radiation dose from such an operation would already be included in the estimated doses to the maximally exposed workers and worker populations listed in Table 4-25.

4.1.7.3.1.2 Public Health Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of about 0.009 to 0.017 microgram per cubic meter for the operating modes. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from operations period activities could result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air, and from exposure to radioactive noble gas fission products, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations. Krypton-85 and other noble gas fission products would be very small contributors to dose and potential radiological impacts, less than 0.01 percent of the dose from radon-222 and its decay products (see Section 4.1.2.3.2).

Section 4.1.2.3.2 presents estimates of dose to the public for the handling, emplacement, and continuing development (operations) period. Table 4-26 presents these doses and the potential radiological health impacts to the public for that period. Potential radiological health impacts would be very small. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.000022 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.012 to 0.42.

Table 4-26. Radiation doses and radiological health impacts to the public during the operations period.[a,b,c,d]

Dose and health impact	Operating mode: Higher-temperature (Entire period)	Lower-temperature (Entire period)	Higher-temperature (Maximum annual)	Lower-temperature (Maximum annual)
Maximally exposed individual[e]				
Dose (millirem)	12	17 - 43	0.73	1.0 - 1.3
Latent cancer fatality probability	6.0×10^{-6}	$0.83 - 2.2 \times 10^{-5}$	3.7×10^{-7}	$5.2 - 6.7 \times 10^{-7}$
Exposed 80-km population[f]				
Collective dose (person-rem)	230	320 - 830	14	20 - 26
Number of latent cancer fatality	0.12	0.16 - 0.42	0.0071	0.010 - 0.013

a. Numbers are rounded to two significant figures.
b. Source: Table 4-4.
c. Greater than 99.9 percent of the dose would be from naturally occurring radon-222 and decay products.
d. Fuel handling activities during the operation and monitoring phase would last 24 years. Emplacement activities would last 24 years with no aging, and 50 years with aging. Continued subsurface development activities would last 22 years.
e. Individual located at the southern boundary of the land withdrawal area for all of the operations period (24 or 50 years).
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).

4.1.7.3.2 *Monitoring Period*

This period would last 76 years under the higher-temperature operating mode and up to 300 years under lower-temperature operating modes. The first 3 years of this period would include decontamination of surface fuel handling facilities in preparation for the long periods of monitoring and maintenance to follow, and ultimately for closure. Only monitoring and maintenance activities would take place during the remainder of the period, including periodic replacement of the solar facility components. Most of the potential operating modes would include active ventilation during this period, but 250 years of natural ventilation could be used, during which there would be lower ventilation flow rates (see Section 2.1.1.2.2).

4.1.7.3.2.1 Occupational Impacts

Industrial Hazards. Table 4-27 lists health and safety impacts from common industrial hazards for the monitoring period, including decontamination activities. Impacts were estimated separately for the surface facility decontamination operations, surface operations to support subsurface monitoring, and subsurface monitoring itself.

About 0.4 fatality would be expected to occur for the higher-temperature operating mode. The range of fatalities predicted for the lower-temperature operating mode is 0.44 to 1.1 fatalities with the largest value for long-term ventilation with aging of the spent nuclear fuel.

Naturally Occurring Hazardous Material. During monitoring and maintenance activities there would be little opportunity for large quantities of dust to be generated for extended periods of time. If necessary, and as discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures such as respiratory protection to control and minimize impacts to workers from releases of cristobalite and erionite during monitoring activities.

Radiological Health Impacts. Occupational radiological health impacts during the monitoring period would be a combination of impacts to surface workers during facility decontamination and subsurface workers during monitoring and maintenance activities. These impacts are presented in Table 4-28.

Table 4-27. Impacts to workers from industrial hazards during the monitoring period.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Involved workers		
Total recordable cases	320	400 - 1,000
Lost work day cases	130	160 - 410
Fatalities	0.31	0.38 - 1.0
Noninvolved workers		
Total recordable cases	55	65 - 150
Lost workday cases	27	32 - 73
Fatalities	0.049	0.057 - 0.13
All workers (totals)[c]		
Total recordable cases	380	470 - 1,200
Lost workday cases	160	190 - 480
Fatalities	0.36	0.44 - 1.1

a. Values are rounded to two significant figures.
b. Source: Appendix F, Table F-31.
c. Totals might differ from sums of values due to rounding.

Table 4-28. Radiation dose and radiological health impacts to workers during the monitoring period.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker[c]		
Dose, rem		
Involved	18	18
Noninvolved	1.8	1.8
Probability of latent cancer fatality		
Involved	0.0072	0.0072
Noninvolved	0.00072	0.00072
Worker population		
Collective dose (person-rem)		
Involved	1,100	1,500 - 4,300
Noninvolved	36	46 - 140
Total[d]	**1,100**	**1,500 - 4,400**
Number of latent cancer fatalities		
Involved	0.44	0.60 - 1.7
Noninvolved	0.014	0.018 - 0.056
Total[d]	**0.44**	**0.60 - 1.8**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-32.
c. Maximally exposed worker is a subsurface involved worker who works in the subsurface environment for 50 years.
d. Totals might differ from sums of values due to rounding.

The estimated radiological health impacts to the worker population for the 76- to 300-year monitoring period would range from 0.44 to 1.8 latent cancer fatalities. The relatively wide range in impacts is due mainly to the differences in the length of the monitoring periods. Estimated radiological health impacts to the maximally exposed individual would be 18 rem for the range of operating modes, with a corresponding probability of latent cancer fatality of 0.0072. Estimated doses and radiological health impacts to the maximally exposed worker are based on a 50-year working lifetime. The principal contributor to radiological health impacts would be from subsurface facility monitoring and maintenance activities.

4.1.7.3.2.2 Public Health Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of 0.009 to 0.017 microgram per cubic meter; however, these concentrations are likely more representative of operations period activities while those during the monitoring period would be even lower. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from monitoring period activities would result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air. No releases of radioactive material or radiation dose to the public are anticipated for decontamination activities (DIRS 152010-CRWMS M&O 2000, pp. 55-56).

Section 4.1.2.3.2 presents estimates of dose to the public for the monitoring period. Table 4-29 lists these doses and potential radiological health impacts to the public for that period. Potential radiological health impacts would be low. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.000031 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.75 to 1.7. Because of the length of the monitoring period compared to other project periods, most of the estimated radiological impacts to the public would occur during this period.

Table 4-29. Radiation doses and radiological health impacts to the public during the monitoring period.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Dose and health impact	Entire period		Maximum annual	
Maximally exposed individual[e]				
Dose (millirem)	29	30 - 62	0.41	0.59 - 0.89
Latent cancer fatality probability	1.5×10^{-5}	$1.5 - 3.1 \times 10^{-5}$	2.1×10^{-7}	$3 - 4.4 \times 10^{-7}$
Exposed 80-kilometer population[f]				
Collective dose (person-rem)	600	1,500 - 3,500	8	11 - 17
Number of latent cancer fatalities	0.31	0.75 - 1.7	0.004	0.0057 - 0.0085

a. Numbers are rounded to two significant figures.
b. Source: Table 4-5.
c. All dose would be from naturally occurring radon-222 and decay products.
d. Monitoring and maintenance period would last from 76 to 300 years.
e. Individual located at the southern boundary of the land withdrawal area for 10 years.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

4.1.7.4 Impacts to Occupational and Public Health and Safety from Closure

This section contains estimates of health and safety impacts to workers and to members of the public for the closure phase. The length of this phase depends on the operating mode. The higher-temperature operating mode closure phase would last 10 years, while closure for the lower-temperature operating mode would range from 11 to 17 years in length.

4.1.7.4.1 *Occupational Impacts*

Industrial Hazards. Table 4-30 lists impacts to workers from normal industrial workplace hazards for the closure phase. No workplace industrial fatalities (0.2 to 0.25) would be expected during closure. The range of impacts is due to the differences in the length of the closure period, because closure activities are similar under all operating modes.

Table 4-30. Impacts to workers from industrial hazards during the closure phase.[a,b]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	320	340 - 420
Lost work day cases	150	160 - 200
Fatalities	0.15	0.16 - 0.2
Noninvolved workers		
Total recordable cases	51	53 - 62
Lost workday cases	25	26 - 30
Fatalities	0.045	0.047 - 0.054
All workers (totals)[c]		
Total recordable cases	370	390 - 480
Lost workday cases	180	190 - 230
Fatalities	0.2	0.21 - 0.25

a. Values are rounded to two significant figures.
b. Source: Appendix F, Table F-38.
c. Totals might differ from sums of values due to rounding.

Naturally Occurring Hazardous Material. During closure activities there would be potential for dust to be generated (for example, during preparation and emplacement of excavated rock for backfill). The potential for dust generation, especially in the underground environment, would be less than for subsurface excavation during the construction phase and operations period. As necessary, DOE would use engineering controls and worker protection measures such as those discussed in Section 4.1.7.2.1 for the construction phase to control and minimize potential impacts to workers. Potential impacts would be very small.

Radiological Health Impacts. During the closure phase, subsurface workers would be exposed to radon-222 in the drift atmosphere, to external radiation from radionuclides in the drift walls, and to external radiation from the waste packages. Table 4-31 lists radiological impacts to workers for the closure phase. There is low potential for exposure of surface workers, and most of the radiation dose and potential radiological health impacts would be to subsurface workers. The maximally exposed worker would be a subsurface worker. The estimated radiological health impacts to the worker population for the 10 to 17 year closure phase would range from 0.15 to 0.28 latent cancer fatality. The range in impacts is due mainly to the differences in the length of the phase for the range of operating modes. Estimated radiological health impacts to the maximally exposed individual would range from 6.7 to 13 rem, with a corresponding probability of latent cancer fatality ranging from 0.0027 to 0.0052. The principal sources of exposure to subsurface workers would be from inhalation of radon-222 and its decay products.

4.1.7.4.2 *Public Health Impacts*

Naturally Occurring Hazardous Material. Section 4.1.2.4.1 presents estimated annual average concentrations of cristobalite during the closure phase at the land withdrawal boundary, where members of the public could be exposed. There would be no subsurface excavation during the closure phase, so cristobalite concentrations would be less than for earlier phases. Annual average concentrations of about 0.012 to 0.013 microgram per cubic meter were estimated for the operating modes, and health impacts to

Table 4-31. Radiation dose and radiological health impacts to workers during closure phase.[a,b,c]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker[d]		
Dose, rem		
Involved	6.7	7.9 - 13
Noninvolved	0.36	0.40 - 0.61
Probability of latent cancer fatality		
Involved	0.0027	0.0032 - 0.0052
Noninvolved	0.00014	0.00016 - 0.00024
Worker population		
Collective dose (person-rem)		
Involved	430	480 - 740
Noninvolved	16	18 - 28
Total[e]	450	500 - 770
Number of latent cancer fatalities		
Involved	0.17	0.19 - 0.30
Noninvolved	0.0064	0.0072 - 0.011
Total[e]	***0.18***	***0.2 - 0.31***

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-39.
c. Closure phase would last 10 to 17 years.
d. The maximally exposed individual would be a subsurface worker.
e. Totals might differ from sums of values due to rounding.

the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Potential impacts would be very small.

Radiological Health Impacts. Potential radiation-related health impacts to the public from closure activities would result from exposure to radon-222 and its decay products released in the subsurface exhaust ventilation air. Section 4.1.2.4.2 presents estimates of dose to the public for the closure phase. Table 4-32 lists the estimated dose and radiological health impacts.

Table 4-32. Radiation dose and radiological health impacts to public for the closure phase.[a,b,c,d]

Dose and health impact	Operating mode: Entire phase, Higher-temperature	Entire phase, Lower-temperature	Maximum annual, Higher-temperature	Maximum annual, Lower-temperature
Maximally exposed individual[e]				
Dose (millirem)	3	4.3 - 9.4	0.4	0.57 - 0.87
Latent cancer fatality probability	1.5×10^{-6}	$2.2 - 4.7 \times 10^{-6}$	2.0×10^{-7}	$2.8 - 4.3 \times 10^{-7}$
Exposed 80-km population[f]				
Collective dose (person-rem)	57	83 - 180	7.4	10 - 16
Number of latent cancer fatality	0.028	0.041 - 0.090	0.0037	0.0052 - 0.0081

a. Numbers are rounded to two significant figures.
b. Source: Table 4-7.
c. All dose would be from naturally occurring radon-222 and decay products.
d. The closure phase would last from 10 to 17 years.
e. Individual located at the southern boundary of the land withdrawal area.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

Potential radiological health impacts would be small. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.0000047 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.028 to 0.090. Differences in potential impacts are due mainly to differences in the length of the closure phase.

4.1.7.5 Total Impacts to Occupational and Public Health and Safety for All Phases

This section presents estimates of the total human health and safety impacts to workers and members of the public from proposed activities at the Yucca Mountain repository. It describes the total impacts from activities during the construction, operation and monitoring, and closure phases to workers from industrial hazards and radiation exposure, and to members of the public from radiation exposure.

Among other operating factors, total project impacts would depend on the duration of the project. The higher-temperature operating mode would last 115 years, while the lower-temperature operating mode would last from 171 to 341 years. These time periods include a 5-year construction phase and variable time periods for the operation and monitoring phase (100 to 324 years) and closure phase (10 to 17 years), as discussed in the previous sections. In general, the highest potential health and safety impacts would occur during the operation and monitoring phase.

4.1.7.5.1 *Total Impacts to Workers from Industrial Hazards for All Phases*

Total impacts to workers from industrial hazards for the entire project are shown in Table 4-33. The estimated number of workplace fatalities would range from 2.0 for the higher-temperature operating mode to 3.3 for the upper end of the lower-temperature operating mode.

Table 4-33. Total impacts to workers from industrial hazards for all phases.[a]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature[b]
Involved workers		
Total recordable cases	2,200	2,500 - 3,300
Lost work day cases	1,000	1,200 - 1,500
Fatalities	1.5	1.8 - 2.6
Noninvolved workers		
Total recordable cases	460	500 - 720
Lost workday cases	230	250 - 350
Fatalities	0.45	0.48 - 0.68
All workers (totals[c,d])		
Total recordable cases	2,700	3,000 - 4,000
Lost workday cases	1,300	1,500 - 1,900
Fatalities	2.0	2.3 - 3.3

a. Numbers are rounded to two significant figures.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. Source: Tables 4-21, 4-24, 4-27, and 4-30.
d. Totals might differ from sums of values due to rounding.

4.1.7.5.2 *Total Radiological Health Impacts to Workers for All Phases*

Total radiation dose and radiological health impacts to workers for the entire project (all phases) are listed in Table 4-34. Dose and impact for the maximally exposed individual worker are listed for a 50-year working lifetime. The collective dose to the worker population and potential radiological health impacts are shown for the entire project duration, ranging from 115 years for the higher-temperature operating mode up to 341 years for the lower-temperature operating mode.

Table 4-34. Total radiation dose and radiological health impacts to workers for all phases.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker[d]		
Dose, rem		
Involved	18	18 - 30
Noninvolved	1.8	1.8
Probability of latent cancer fatality		
Involved	0.0072	0.0072 - 0.012
Noninvolved	0.00072	0.00072
Worker population		
Collective dose (person-rem)		
Involved	9,700	11,000 - 17,000
Noninvolved	240	280 - 360
Total[e]	**10,000**	**11,000 - 17,000**
Number of latent cancer fatalities		
Involved	3.9	4.4 - 6.8
Noninvolved	0.092	0.11 - 0.14
Total[e]	**4.0**	**4.4 - 6.8**

a. Numbers are rounded to two significant figures.
b. Source: Tables 4-22, 4-25, 4-28, and 4-31 for the construction phase, operations period, monitoring period, and closure phase, respectively.
c. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
d. For a 50-year working lifetime.
e. Totals might differ from sums of values due to rounding.

The maximally exposed worker is a subsurface worker whose 50-year working lifetime would span the 50-year operations period needed for aging of spent nuclear fuel. This worker would be a locomotive operator or brakeman who is involved in the transport and emplacement of the spent nuclear fuel. Receiving an estimated radiation dose of about 30 rem, the probability of incurring a latent cancer fatality would be about 0.0012 for this individual.

The total estimated number of latent cancer fatalities that could occur in the repository workforce from the radiation dose received over the entire project would be about 4 for the 115 years of exposure during the higher-temperature operating mode. The number of latent cancer fatalities would range from 4.4 to 6.8, for the 171 to 341 years, respectively, of the lower-temperature operating mode. About 80 percent of the dose and associated risk of latent cancer fatality would occur during the operations period for surface and subsurface workforce. The principal source of exposure would be external radiation from spent nuclear fuel handling in surface facilities and waste package emplacement in the subsurface facility. Inhalation of radon-222 and its decay products by subsurface workers would account for 25 percent of the total worker dose. Ambient radiation exposure to subsurface workers would account for about 10 percent of the total worker dose.

4.1.7.5.3 *Total Radiological Health Impacts to the Public for All Phases*

The estimated radiation dose and radiological health impacts to the public for the entire project—which includes the period prior to final repository closure—are listed in Table 4-35. Dose and the potential radiological impact are listed for the offsite maximally exposed individual, assumed to reside continuously for a 70-year lifetime at the southern boundary of the land withdrawal area. This individual would have a probability of latent cancer fatality of 0.000031 or less from exposure to radionuclides released from the repository during the preclosure period. More than 99.9 percent of the potential health impact would be from naturally occurring radon-222 and its decay products released in exhaust

Table 4-35. Total dose and radiological impacts to the public for all phases.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature[e]	Higher-temperature	Lower-temperature[e]
Dose and health impact	Entire project		Maximum annual	
Maximally exposed individual[f]				
Dose (millirem)	31	44 - 62	0.73	1 - 1.3
Latent cancer fatality probability	1.6×10^{-5}	$2.2 - 3.1 \times 10^{-5}$	3.7×10^{-7}	$5.2 - 6.7 \times 10^{-7}$
Exposed 80-km population[g]				
Collective dose (person-rem)	930	1,900 - 3,900	14	20 - 26
Number of latent cancer fatality	0.46	0.97 - 2	0.0071	0.010 - 0.013

a. Numbers are rounded to two significant figures.
b. Source: Table 4-8, Section 4.1.2.5.
c. Greater than 99.9 percent of dose would be from naturally occurring radon-222 and decay products.
d. Project would last from 115 to 341 years.
e. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
f. Individual located at the southern boundary of the land withdrawal area for a 70-year lifetime including all of the operations period (24 or 50 years) with the remainder during the monitoring period.
g. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

ventilation air. The highest annual radiation dose would range from 0.73 to 1.3 millirem, less than 1 percent of the annual 200-millirem dose to members of the public in Amargosa Valley from ambient levels of naturally occurring radon-222 and its decay products (Chapter 3, Section 3.1.8.2).

The collective or population dose and associated radiological health impacts are listed in Table 4-35 for the population within 80 kilometers (50 miles) for the entire project duration, ranging from 115 years for the higher-temperature operating mode up to 341 years for the lower-temperature operating mode. An estimated 0.46 latent cancer fatality would occur for the higher-temperature operating mode, and from 0.97 to 2.0 latent cancer fatalities would occur for the lower-temperature operating mode. Statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause (DIRS 153066-Murphy 2000, p. 8). Assuming this rate would remain unchanged for the estimated population (in 2035) of about 76,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 18,000 members of this population would be expected to die from cancer-related causes. During the time the project was active, the number of cancer deaths unrelated to the project would range from about 30,000 to 89,000 in the general population. Estimated project-related impacts (0.46 to 2 latent cancer fatalities) would be a very small increase (0.007 percent or less) over this baseline. The potential human health impacts of long-term repository performance are discussed in Chapter 5.

4.1.8 ACCIDENT SCENARIO IMPACTS

This section describes the impacts from potential accident scenarios from performance confirmation, construction, operation and monitoring, and closure activities. The analysis is separated into radiological accidents (Section 4.1.8.1) and nonradiological accidents (Section 4.1.8.2). The analysis of radiological accident consequences used the MACCS2 computer code (DIRS 103168-Chanin and Young 1998, all). The receptors would be (1) the *maximally exposed individual,* defined as a hypothetical member of the public at the point on the land withdrawal boundary that would receive the largest dose from the assumed accident scenario, (2) the *involved worker,* a worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the *noninvolved worker*, a worker near the accident but not involved in handling the material, and (4) members of the public who reside within approximately 80 kilometers (50 miles) of the proposed repository. All analysis method details are provided in Appendix H.

The impacts to offsite individuals from repository accidents would be small, with calculated doses of 0.038 rem or less to the maximally exposed offsite individual. Doses to a maximally exposed noninvolved worker would be higher than those to offsite individuals, up to 16 rem. Some of the very unlikely accidents would be expected to severely injure or kill involved workers.

4.1.8.1 Radiological Accidents

The first step in the radiological accident analysis was to examine the initiating events that could lead to facility accidents. These events could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material. They include human-caused events such as aircraft crashes, external fires and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. In addition, the analysis used bounding (plausible upper limit) accident scenarios to represent the impacts from groups of similar accidents. Finally, it evaluated the consequences of the postulated accident scenarios by estimating the potential radiation dose and radiological impacts.

ACCIDENT TYPES

Radiological accidents are unplanned events that could result in exposure of nearby humans to direct radiation or to radioactive material that would be ingested or inhaled.

Nonradiological accidents are unplanned events that could result in exposure of nearby humans to hazardous or toxic materials released to the environment as a result of the accident.

The analysis used accident analyses previously performed by others for repository operation whenever possible to identify potential accidents. DOE reviewed these analyses for their applicability to the repository before using them (see Appendix H). The spectrum of accident scenarios evaluated in the analysis is based on the current conceptual design of the facility. Final facility design details are not available; the final designs could affect both the frequency and consequences of postulated accidents. For areas without final facility design criteria, DOE made assumptions to ensure that the analysis did not underestimate impacts.

The radionuclide *source term* for various accident scenarios could involve several different types of radioactive materials. These would include commercial spent nuclear fuel from both boiling- and pressurized-water commercial reactors (see Appendix A, Section A.2.1), DOE spent nuclear fuel (see Appendix A, Section A.2.2), DOE high-level radioactive waste incorporated in a glass matrix (see Appendix A, Section A.2.3), and weapons-grade plutonium either immobilized in high-level radioactive waste glass matrix or as mixed-oxide fuel (see Appendix A, Section A.2.4). Appendix A contains information on the radionuclide inventories in these materials. The analysis also examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

The analysis used the radionuclide inventories from Appendix A for a representative fuel element to estimate the material that could be involved in an accident. It used the MACCS2 computer program, developed under the guidance of the Nuclear Regulatory Commission, to estimate potential radiation doses to exposed individuals (onsite and offsite) and population groups from postulated accidental releases of radionuclides. Appendix H contains additional information on the MACCS2 program and the models and assumptions incorporated in it.

The analysis considered radiological consequences of the postulated accidents for the following individuals and populations:

- *Involved worker.* A facility worker directly involved in activities at the location where the postulated accident could occur

- *Maximally exposed noninvolved worker (collocated worker).* A worker not directly involved with material unloading, transfer, and emplacement activities, assumed to be 100 meters (330 feet) downwind of the facility where the release occurs

- *Maximally exposed offsite individual.* A hypothetical member of the public at the nearest point to the facility at the site boundary. The analysis determined that the land withdrawal boundary location with the highest potential exposure from an accidental release of radioactive material would be either about 8 or 11 kilometers (5 or 7 miles) from the accident location (at the western boundary of the land withdrawal area analyzed). The maximally exposed individual for a single-point release of material is different than those for a continuous release (see Section 4.1.2) because the maximally exposed individual could not be present continuously at the western boundary because this is government-owned land.

- *Offsite population.* Members of the public within 80 kilometers (50 miles) of the repository site (see Chapter 3)

Ten accident scenarios were analyzed in detail. These scenarios bound the consequences of credible accidents at the repository. They include accidents in the Cask/Handling Area, the Canister Transfer System, the Assembly Transfer System, the Disposal Container Handling Area, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter.

The 10 accident scenarios in Tables 4-36 and 4-37 replace the 16 accident scenarios analyzed in the Draft EIS. The number of scenarios was reduced because several accidents analyzed in the Draft EIS were found to be no longer credible based on design changes, revised system-failure probabilities, and new information on the capability of DOE canisters and transportation casks to withstand drops. Details of these changes are in Appendix H, Section H.2.1.1.

Table 4-36 lists the results of the radiological accident consequence analysis under median, or 50th-percentile meteorological conditions. Table 4-37 lists similar information based on unfavorable meteorological conditions (95th-percentile, or those conditions that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts. Impacts to the noninvolved worker would result from the inhalation of airborne radionuclides and external radiation from the passing plume. Impacts to the maximally exposed offsite individual and the offsite population would result from these exposure pathways and from long-term external exposure to radionuclides deposited on soil during plume passage, subsequent ingestion of radionuclides in locally grown food, and inhalation of resuspended particulates. The analysis did not consider interdiction by DOE or other government agencies to limit long-term radiation doses because none of these doses would be above the Environmental Protection Agency's Protective Action Guides. Interdiction would be likely to occur if the calculated accident doses exceeded these guides.

Table 4-36. Radiological consequences of repository operations accident scenarios for median (50th-percentile) meteorological conditions.

		Maximally exposed offsite individual[c]		Population		Noninvolved worker		Involved worker	
Accident scenario[a,b]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	8.2×10^{-7}	4.1×10^{-10}	4.9×10^{-4}	2.4×10^{-7}	3.6×10^{-4}	1.4×10^{-7}	(e)	(e)
2. Basket drop onto another basket in dryer (PWR fuel)	0.04	8.7×10^{-6}	4.4×10^{-9}	8.9×10^{-4}	4.4×10^{-7}	4.5×10^{-3}	1.8×10^{-6}	(e)	(e)
3. Drop of transfer basket onto another basket in dryer (BWR fuel)	7.4×10^{-3}	6.4×10^{-6}	3.2×10^{-9}	6.0×10^{-4}	3.0×10^{-7}	3.1×10^{-5}	1.2×10^{-8}	(e)	(e)
4. Unsealed DC drop and slapdown in cell (PWR fuel)	8.4×10^{-3}	2.6×10^{-5}	1.3×10^{-8}	2.5×10^{-3}	1.2×10^{-6}	1.3×10^{-2}	5.2×10^{-6}	(e)	(e)
5. Unsealed shipping cask drop in CPP (PWR fuel)	8.7×10^{-3}	3.4×10^{-5}	1.8×10^{-8}	3.0×10^{-3}	1.5×10^{-6}	1.8×10^{-2}	7.4×10^{-6}	(e)	(e)
6. Unsealed shipping cask drop in pool (PWR fuel)	8.7×10^{-3}	2.5×10^{-6}	1.3×10^{-9}	1.5×10^{-3}	7.3×10^{-7}	1.0×10^{-3}	4.1×10^{-7}	(e)	(e)
7. Transporter runaway and derailment (PWR fuel)	1.2×10^{-7}	1.0×10^{-2}	5.0×10^{-6}	0.14	7.3×10^{-5}	3.2	1.3×10^{-3}	(f)	(f)
8. Beyond design basis earthquake in WHB (PWR fuel)	2.0×10^{-5}	1.2×10^{-2}	6.0×10^{-6}	0.63	3.2×10^{-4}	4.9	2.0×10^{-3}	(f)	(f)
9. Earthquake with fire in WTB	2.0×10^{-5}	1.6×10^{-5}	8.0×10^{-9}	8.9×10^{-4}	4.4×10^{-7}	8.2×10^{-4}	3.3×10^{-7}	(f)	(f)
10. Low level waste drum rupture in WTB	0.59	5.7×10^{-10}	2.9×10^{-13}	3.0×10^{-8}	1.4×10^{-11}	2.5×10^{-8}	1.0×10^{-11}	8.8×10^{-5}	3.5×10^{-8}

a. Source: Appendix H
b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.
c. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accident scenarios except 7. For these accidents, the distance would be 8 kilometers (5 miles).
d. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as discussed in Appendix F, Section F.1.1.5.
e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.
f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The *maximum reasonably foreseeable accident scenario* (earthquake, Table 4-37, number 8) for the 95-percent weather conditions would result in an estimated 0.011 additional latent cancer fatality for the same affected population. The more conservative summation of all foreseeable accidents in Table 4-37 results in less than 0.02 additional latent cancer fatality for the exposed population. Thus, the estimated number of latent cancer fatalities for the offsite individuals from accidents would be very small.

The results described in this section assumed that all commercial spent nuclear fuel would arrive at the repository either uncanistered or in canisters not suitable for disposal. In this base case scenario, all of the fuel would have to be handled as bare fuel assemblies in the Waste Handling Building and placed in disposal containers for disposal, as described above. The base case scenario, which assumes that all fuel would have to be handled as bare fuel assemblies, provides a bounding assessment of accident impacts compared to canistered scenarios. The uncanistered fuel, as indicated in Tables 4-36 and 4-37, represents the more meaningful accident risk because of the additional handling operations required and the higher impacts associated with accidents involving bare assemblies. As a consequence, the base case evaluated in this section provides a bounding assessment of accident impacts in relation to the packaging scenarios.

Table 4-37. Radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) meteorological conditions.

Accident scenario[a,b]	Frequency (per year)[b]	Maximally exposed offsite individual[c] Dose (rem)	LCFi[d]	Population Dose (person-rem)	LCFp[d]	Noninvolved worker Dose (rem)	LCFi	Involved worker Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	3.3×10^{-6}	1.7×10^{-9}	4.0×10^{-2}	2.0×10^{-5}	2.0×10^{-3}	8.0×10^{-7}	(e)	(e)
2. Basket drop onto another basket in dryer (PWR fuel)	0.04	3.2×10^{-5}	1.6×10^{-8}	4.7×10^{-2}	2.3×10^{-5}	2.3×10^{-2}	9.2×10^{-6}	(e)	(e)
3. Drop of transfer basket onto another basket in dryer (BWR fuel)	7.4×10^{-3}	2.3×10^{-5}	1.2×10^{-8}	3.0×10^{-2}	1.4×10^{-5}	1.6×10^{-4}	6.4×10^{-8}	(e)	(e)
4. Unsealed DC drop and slapdown in cell (PWR fuel)	8.4×10^{-3}	9.3×10^{-5}	4.7×10^{-8}	0.12	6.2×10^{-5}	7.4×10^{-2}	3.0×10^{-5}	(e)	(e)
5. Unsealed shipping cask drop in CPP (PWR fuel)	8.7×10^{-3}	1.1×10^{-4}	5.5×10^{-8}	0.14	7.2×10^{-5}	0.10	4.1×10^{-5}	(e)	(e)
6. Unsealed shipping cask drop in pool (PWR fuel)	8.7×10^{-3}	1.0×10^{-5}	5.0×10^{-9}	0.12	6.0×10^{-5}	6.0×10^{-3}	2.4×10^{-6}	(e)	(e)
7. Transporter runaway and derailment (PWR fuel)	1.2×10^{-7}	3.8×10^{-2}	1.9×10^{-5}	4.3	2.2×10^{-3}	16	6.4×10^{-3}	(e)	(e)
8. Beyond design basis earthquake in WHB (PWR fuel)	2.0×10^{-5}	3.8×10^{-2}	1.9×10^{-5}	21	1.1×10^{-2}	25	9.8×10^{-3}	(f)	(f)
9. Earthquake with fire in WTB	2.0×10^{-5}	5.4×10^{-5}	2.7×10^{-8}	3.1×10^{-2}	1.5×10^{-5}	6.5×10^{-3}	2.6×10^{-6}	(f)	(f)
10. Low level waste drum rupture in WTB	0.59	1.6×10^{-9}	8.0×10^{-13}	1.1×10^{-6}	5.3×10^{-10}	2.0×10^{-7}	8.0×10^{-11}	8.8×10^{-5}	3.5×10^{-8}

a. Source: Appendix H.
b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.
c. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accidents except 7. For these accidents, the distance would be 8 kilometers (5 miles).
d. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as discussed in Section F.1.1.5.
e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.
f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The analysis also evaluated the probability of an aircraft crash onto storage modules which could be used in a surface aging facility. A military aircraft crash onto a storage module was found to be a reasonably foreseeable event; however, the analysis determined that the aircraft would not penetrate the storage module and no release would occur. A crash of a commercial jet airliner into the surface aging facility was also evaluated, even though the probability of such an event is not reasonably foreseeable. The results of the evaluation also indicate no penetration of the storage modules and no release of radiological materials. Details are provided in Appendix H, Section H.2.1.3.

In addition to the reasonably foreseeable accidents summarized in this section, DOE evaluated a hypothetical beyond-credible event (annual probability less than 1 in 10 million) involving an aircraft crash into the repository (see Appendix H, Section H.2.1.5.1). It was determined that an aircraft crash into the Waste Handling Building would result in the maximum estimated consequences. DOE assumed that evacuation of potentially exposed individuals would occur one day after the event, and also that contaminated food and water would be monitored and confiscated if necessary. The dose to the maximally exposed individual was estimated to be 4.5 rem, with a 0.0023 probability of a latent cancer fatality. The dose to the population within 80 kilometers (50 miles) was estimated to be 78 person-rem, with 0.039 latent cancer fatality resulting from this dose.

4.1.8.2 Nonradiological Accidents

A potential release of hazardous or toxic materials during postulated operational accidents involving spent nuclear fuel or high-level radioactive waste at the repository would be very unlikely. Because of the large quantities of radioactive material, radiological considerations would outweigh nonradiological concerns. The repository would not accept hazardous waste as defined by the Resource Conservation and Recovery Act. Some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. However, they would be in a vitrified glass matrix that would make the exposure of workers or members of the public from operational accidents highly unlikely. Appendix A contains more information on the inventory of potentially hazardous materials.

Some potentially nonradioactive hazardous or toxic substances would be present in limited quantities at the repository as part of operational requirements. Such substances would include liquid chemicals such as cleaning solvents, sodium hydroxide, sulfuric acid, and various solid chemicals (see Section 4.1.3.2). These substances are in common use at other DOE sites. Section 4.1.7 describes potential impacts to workers from normal industrial hazards in the workplace (which includes industrial accidents). The statistics used in the analysis were derived from DOE accident experience at other sites. Impacts to members of the public would be unlikely because the chemicals would be mostly liquid and solid so that any release would be confined locally. (For example, chlorine at the site used for water treatment would be in powder form, so a gaseous release of chlorine would not be possible. Propane gas would not be stored at the site.)

Section 4.1.12.2 describes the quantities of solid hazardous waste generated during repository operations. The construction and closure phases would not generate liquid hazardous waste. The generation, storage, and shipment off the site of solid and liquid hazardous waste generated during operations would represent minimal incremental risk from accidents. Impacts to workers from industrial accidents in the workplace are part of the statistics presented in Appendix F, Section F.2.

4.1.8.3 Sabotage

In the aftermath of the tragic events of September 11, DOE is continuing to assess measures that it could take to minimize the risk or potential consequences of radiological sabotage or terrorist attacks against our Nation's proposed monitored geologic repository.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level radioactive waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (prior to closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by Federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

Current Nuclear Regulatory Commission regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides "high assurance that activities involving spent nuclear fuel and high-level waste do not constitute an unreasonable risk to public health and safety." The regulations require that spent nuclear fuel and high-level radioactive waste be stored in a protected area such that:

- Access to the material requires passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, be continually monitored, and be protected by an active alarm system.
- Adequate illumination must be provided for observation and threat assessment.
- The area must be monitored by random patrol.
- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

A trained, equipped, and qualified security force is required to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat. Liaison with a response force is required to permit timely response to unauthorized entry or activities. In addition, the Nuclear Regulatory Commission requires (10 CFR Part 63, by reference to 10 CFR Part 72) that comprehensive receipt, periodic inventory, and disposal records be kept for spent nuclear fuel and high-level radioactive waste in storage. A duplicate set of these records must be kept at a separate location.

DOE believes that the safeguards applied to the proposed repository should involve a dynamic process of enhancement to meet threats, which could change over time. Repository planning activities would continue to identify safeguards and security measures that would further protect fixed facilities from terrorist attack and other forms of sabotage. Additional measures that DOE could adopt include:

- Facilities with thicker reinforced walls and roofs designed to mitigate the potential consequences of the impact of airborne objects
- Underground or surface bermed structures to lessen the severity of damage in cases of aircraft crashes
- Additional doors, airlocks, and other features to delay unauthorized intrusion
- Additional site perimeter barriers to provide enhanced physical protection of site facilities
- Active denial systems to disable any adversaries, thereby preventing access to the facility

Although it is not possible to predict if sabotage events would occur, and the nature of such events if they did occur, DOE examined various accident scenarios that approximate the types of consequences that could occur. These accidents and their consequences are discussed in Section 4.1.8.1.

4.1.9 NOISE IMPACTS

This section describes possible noise impacts to the public (nuisance noise) and workers (occupational noise) from performance confirmation, construction, operation and monitoring, and closure activities. Repository areas that could generate elevated noise levels include the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas. The following discussion identifies potential impacts that primarily would affect workers during routine operations. Overall, however, the potential for noise impacts to the public would be very small due to the distances of residences from these areas. Section 4.1.4.2 discusses noise impacts on wildlife.

4.1.9.1 Noise Impacts from Performance Confirmation

As part of site characterization, DOE has evaluated existing noise conditions in the Yucca Mountain region. The noise associated with site characterization activities, which has included that from construction, equipment, drilling equipment, and occasional blasting, has not resulted in noticeable impacts. Because performance confirmation activities would be similar to those for site characterization, no impacts would be expected.

4.1.9.2 Noise Impacts from Construction, Operation and Monitoring, and Closure

Sources of noise in the analyzed land withdrawal area during the construction phase would include activities at the North Portal and Ventilation Shaft Operations Areas and South Portal Development Area involving heavy equipment (bulldozers, graders, loaders, pavers, etc.), cranes, ventilation fans, and diesel generators. Sources of noise during the operation and monitoring phase would include transformer noise, compressors, ventilation fans, air conditioners, and a concrete batch plant. Ventilation fans would have silencers that would keep noise levels below 85 dBA (see Chapter 3, Section 3.1.9 for an explanation of noise measurements) at a distance of 3 meters (10 feet) (DIRS 100235-CRWMS M&O 1997, p. 107). The Occupational Safety and Health Administration has identified that the maximum permissible continuous noise level that workers may be exposed to without controls is 90 dBA [29 CFR 1910.95(b)(2)].

The distance from the North Portal Operations Area to the nearest point on the boundary of the analyzed land withdrawal area analyzed would be about 11 kilometers (7 miles) due west. The distance from the South Portal Development Area to the nearest point on the land withdrawal area boundary would also be about 11 kilometers due west. The point on the boundary closest to a Ventilation Shaft Operations Area would be about 7 kilometers (4 miles) (DIRS 104852-YMP 1997, all).

To establish the propagation distance of repository-generated noise for analysis purposes, DOE used an estimated maximum sound level [132 decibels, A-weighted (dBA) for heavy construction equipment, although heavy trucks generate sound levels of between 70 and 80 dBA at 15 meters (50 feet)]. An analysis determined the distance at which that noise would be at the lower limit of human hearing (20 dBA). The calculated distance was 6 kilometers (3.7 miles). Thus, noise impacts would be unlikely at the land withdrawal area boundary.

Because the distance between repository noise sources and a hypothetical individual at the land area withdrawal boundary would be large enough to reduce the noise to background levels and because there would be no residential or community receptors at the withdrawal area boundary [the nearest housing is in Amargosa Valley about 22 kilometers (14 miles) from the repository site], DOE expects no noise impacts to the public from repository construction and operations.

Workers at the repository site could be exposed to elevated levels of noise. Small impacts such as speech interference between workers and annoyance to workers would occur. However, worker exposures during all *repository phases* would be controlled such that impacts (such as loss of hearing) would be unlikely. Engineering controls would be the primary method of noise control. Hearing protection would be required, as needed, as a supplement to engineering controls.

Noise impacts associated with closure would be similar to those associated with construction and operations. Therefore, DOE expects no noise impacts to the public and workers.

4.1.10 AESTHETIC IMPACTS

This section describes potential aesthetic impacts from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. These activities would not cause adverse impacts to aesthetic or visual resources in the region. The analysis of such impacts considered the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The analysis gave specific consideration to scenic quality, visual sensitivity, and distance from observation points.

Yucca Mountain has visual characteristics fairly common to the region (a scenic quality rating of C), and visibility of the repository site from publicly accessible locations is low or nonexistent. The intervening Striped Hills and the low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near the Town of Amargosa Valley, approximately 22 kilometers (14 miles) away. There is no public access to the north or east of the site to enable viewing of the facilities. The only structures that could potentially be visible from the west and exceed the elevation of the southern ridge of Yucca Mountain [1,500 meters (4,900 feet)] would be the ventilation exhaust stacks (numbering 3 to 9) and support structures that could be located along the crest of the mountain. The exhaust stacks could be approximately 15 to 18 meters (50 to 60 feet) high, but a lower profile design could be implemented. The ventilation system would include intake and exhaust stacks, support structures, and access roads. The ventilation system would be constructed and maintained on approximately 105 acres and would include approximately 30 structures (DIRS 153849-DOE 2001, p. 2-33). Some of the exhaust stacks would likely be located along the crest of the mountain, while the intakes would be constructed along the eastern side of the ridge. The height of the ventilation intake structures would be lower than the exhaust stacks and would be constructed at lower elevations. Therefore, the intake stacks would not be as likely to impact the area aesthetically as the exhaust stacks. The presence of exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to Native Americans.

The intake and exhaust ventilation stacks might be angled, thereby lowering the height of the structure and lessening impact. Recontouring the area in the vicinity of the ventilation system structures and the use of natural vegetation as screening would also lessen potential impact. Because of the height of the ventilation stack structures above Yucca Mountain, the Federal Aviation Administration or the Air Force might require flashing beacon lights atop the stacks. If beacons were required, they could be visible for a great distance, especially west of Yucca Mountain. Closure activities, such as dismantling facilities and reclaiming the site, would improve the visual quality of the landscape. Adverse impacts to the visual quality due to closure would be unlikely.

DOE would provide lighting for operation areas at the repository. This lighting could be visible from public access points, especially from the west due to the ventilation structures atop Yucca Mountain. There would not be significant visual impacts due to repository lighting to users of Death Valley National Park. The towns of Amargosa Valley, Beatty, and Pahrump, located between the park and the repository, probably would cause greater impact to the nightly *viewshed* than operational lighting of the repository. The visual impact of the lighting from Las Vegas would also have significantly more impact in the region than that of the proposed repository. The use of shielded or directional lighting at the repository would limit the amount of light that could be viewed from outside the repository operational area.

As described in Section 4.1.1.2, land disturbance for the operating modes would not differ greatly, ranging from 4.3 to 6.0 square kilometers (1,000 to 1,500 acres), a small fraction of the 600 square kilometers withdrawn for the repository. The aesthetic impacts of the land disturbance resulting from implementation of the Proposed Action design would be temporary.

4.1.11 IMPACTS TO UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to residential water, energy, materials, and site services from performance confirmation, construction, operation and monitoring, and closure activities. The scope of the analysis included electric power use, fossil-fuel and oil and lubricant consumption, consumption of construction materials, and onsite services such as emergency medical support, fire protection, and security and law enforcement. The analysis compared needs to available capacity. The region of influence would include the local, regional, and national supply infrastructure that would have to satisfy the needs. The analysis used engineering estimates of requirements for construction materials, utilities, and energy.

Construction activities would occur during both the construction and the operation and monitoring phases. Table 4-38 lists electric energy, fossil-fuel, and oil and lubricant use during the different phases. Table 4-39 lists construction material use. Both tables list comparative values for the higher-temperature operating mode and a range of values for the lower-temperature operating mode. DOE prorated impacts to site services, if any, with those to the commodity areas to produce an estimate of overall impacts.

Overall, DOE expects only small impacts to residential water, energy, materials, and site services from the Proposed Action. DOE would, however, have to enhance the electric power delivery system to the Yucca Mountain site for the operating modes considered.

4.1.11.1 Impacts to Utilities, Energy, Materials, and Site Services from Preconstruction Testing and Performance Confirmation

DOE would obtain utilities, energy, and materials for preconstruction testing and performance confirmation activities from existing sources and suppliers. Water would come from existing wells. Power would come from regional suppliers to the existing Nevada Test Site transmission system. Based on site characterization activities, these activities would not cause meaningful impacts to regional utility, energy, and material sources. In addition, DOE would continue to use such existing site services as emergency medical support, fire protection, and security and law enforcement (as described in Chapter 3, Section 3.1.11.3) during preconstruction testing and performance confirmation.

4.1.11.2 Impacts to Utilities, Energy, Materials, and Site Services from Construction, Operation and Monitoring, and Closure

Residential Water

Population growth associated with the Proposed Action could affect regional water resources. Based on the information in Section 4.1.6, in 2030 the Proposed Action would result in a maximum population increase of about 6,200 in Clark and Nye Counties. About 80 percent of these people would live in Clark County and about 20 percent in Nye County. Whether domestic water needs were satisfied predominantly from surface-water sources, as is the case for most of Clark County, or from groundwater sources, as for most of Nye County, these relatively small increases in population would have very minor impacts on existing water demands.

The maximum project-related population increase for Clark County would amount to about 0.4 percent of the 2000 population and less than 0.2 percent of the County's population in 2030 (see Chapter 3, Section 3.1.7). Correspondingly, the associated increase in water demand in the county as a result of the proposed project would be very small. The population of Indian Springs in Clark County would increase by a projected maximum of about 180 as a result of the Proposed Action. This number represents about 14 percent of the 2000 Indian Springs population and, based on a Las Vegas Valley average demand for domestic water of 720 liters (190 gallons) per day per person (DIRS 148196-SNWA 1999, all), would require a quantity of water that is about 9 percent of the community's quasimunicipal groundwater

Table 4-38. Electricity and fossil-fuel use for the Proposed Action.[a]

Phase	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Phase/activity durations (years)		
Construction phase	5	5
Operations and monitoring phase		
Operations	24	24 or 50
Monitoring	76	99 - 300
Closure phase	10	11 - 17
Total	***115***	***171 - 341***[a]
Peak electric power (megawatts)		
Construction phase	25	25
Operations and monitoring phase		
Operations	47	40 - 54
Monitoring	7.7	7.8 - 15
Closure phase	10	10 - 18
Maximum	*47*	*40 - 54*
Electricity use (1,000 megawatt-hours)		
Construction phase	150	190 - 210
Operations and monitoring phase		
Operations	5,200	5,300 - 9,200
Monitoring	4,800	9,700 - 29,000
Closure phase	720	790 - 1,300
Total	***11,000***	***16,000 - 36,000***[a]
Fossil fuel (million liters)		
Construction phase	5.5	5.5 - 6
Operations and monitoring phase		
Operations	360	370 - 500
Monitoring	2.3	2.6 - 13
Closure phase	5.2	5.1 - 6.6
Total	***370***	***380 - 510***[a]
Oils and lubricants (million liters)		
Construction phase	2.6	3.1 - 3.5
Operations and monitoring phase		
Operations	8.5	9.8 - 18
Monitoring	9	13 - 53
Closure phase	2	1.8 - 3
Total	***22***	***33 - 71***[a]

a. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

withdrawal in 1997 [0.51 million cubic meters (410 acre-feet)] (DIRS 102170-NDCNR 1998, all). DOE expects the population of Indian Springs to be larger by 2030 and on a percentage basis, the contribution (and associated water demand) from project-related growth would be smaller than current numbers. However, this small community would be more likely to be affected by projected growth than other areas in Clark County.

In Nye County, estimates of domestic water demand for 1995 are about 750 liters (200 gallons) per day per person (DIRS 104888-Le Strange 1997, Table 10). At this demand, the project-related increase in Nye County population would result in an additional water demand of about 0.30 million cubic meters (240 acre-feet) of water per year. This represents about 0.3 percent of the water use in Nye County in 1995. As indicated in Section 4.1.6, most (about 92 percent) of the project-related growth in Nye County would occur in Pahrump. This would equate to adding about 0.28 million cubic meters (220 acre-feet) to Pahrump's annual water demand, which represents about 0.9 percent of the 1995 Pahrump water

Table 4-39. Construction material use for the Proposed Action.[a]

Usage	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Phase/activity durations (years)		
Construction phase	5	5
Operations and monitoring phase		
Operations	24	24 or 50
Monitoring	76	99 - 300
Closure phase	10	11 - 17
Total	***115***	***171 - 341[a]***
Concrete (1,000 cubic meters)		
Construction phase	420	490 - 500
Operations and monitoring phase		
Operations	240	350 - 880
Monitoring	0	0
Closure phase	3	3 - 5
Total	***670***	***850 - 1,400[a]***
Cement (1,000 metric tons)		
Construction phase	160	190
Operations and monitoring phase		
Operations	100	150 - 340
Monitoring	0	0
Closure phase	1.2	1.2 - 1.9
Total	***250***	***310 - 530[a]***
Steel (1,000 metric tons)		
Construction phase	100	120
Operations and monitoring phase		
Operations	62	150 - 180
Monitoring	0	0
Closure phase	0.03	0.04
Total	***160***	***270 - 300[a]***
Copper (1,000 metric tons)		
Construction phase	0.2	0.23
Operations and monitoring phase		
Operations	0.08	0.24 - 0.6
Monitoring	0	0
Closure phase	0	0
Total	***0.3***	***0.5 - 0.86[a]***

a. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

withdrawal of 30 million cubic meters (24,000 acre-feet). By 2030, when the peak population increases would occur, the project-related increase in water demand would be an even smaller percentage of the total Nye County and Pahrump water need. The increase in domestic water demand in Nye County as a result of the proposed project would be very small.

Residential Sewer

Sewer utilities could be affected by population growth associated with the Proposed Action. In Clark County, where most of the population growth would take place, the fact that the maximum project-related population increase would amount to about 0.4 percent of the 2000 population indicates that impacts to the populous areas of the county (that is, the Las Vegas Valley) would be very small. In Indian Springs, where project-related growth would be a more substantial portion of the community population, small treatment facilities designed for a specific area or individual household septic tank systems would accommodate wastewater treatment needs. In either case, the added population would not be likely to cause overloading to a sewer utility.

Growth in Nye Country from the Proposed Action would be likely to occur primarily in the Pahrump area. There is no reason to believe that project-related population increases would overload a sewer utility. Again, small, limited-service treatment facilities or individual septic tank and drainage field systems would provide the primary wastewater treatment capacities.

Electric Power

During the construction phase, the demand for electricity would increase as DOE operated two or three tunnel boring machines and other electrically powered equipment. The tunnel boring machines would account for more than half of the demand for electricity during the construction phase. The estimated peak demand for electric power during the construction phase would be about 25 megawatts with use varying between about 150,000 and 210,000 megawatt-hours, depending on the operating mode. Excavation activities for the operating modes would use two or three tunnel boring machines. However, the operations time would increase for the lower-temperature operating mode because of the increased tunnel lengths.

As discussed in Chapter 3, Section 3.1.11.2, the current electric power supply line has a peak capacity of only 10 megawatts. DOE, therefore, is evaluating modifications and upgrades to the site electrical system, as discussed below, under Repository Electric Power Supply Options.

During the operations period, the development of emplacement drifts would continue in parallel with emplacement activities. During this period, the peak electric power demand would be between 40 and 54 megawatts, depending on the operating mode.

Following the completion of excavation activities, the demand for electric power would drop to about 21 to 34 megawatts and would continue to decrease, following the completion of emplacement and decontamination activities, to less than 15 megawatts for monitoring and maintenance activities. The closure phase would last from 10 to 17 years, depending on the operating mode. The peak electric power demand would be less than 18 megawatts for either of the operating modes during closure.

The repository demand for electricity would be well within the expected regional capacity for power generation. Nevada Power Company, for example, experienced a growth in peak demand of nearly 30 percent from 1993 to 1997 and has demonstrated the ability to meet customer demand in this high-growth environment through effective planning (DIRS 103284-Vogel 1998, all). Nevada Power's current planning indicates that it intends to maintain a reserve capacity of 12 percent. In 2010, at the beginning of the operation and monitoring phase, Nevada Power projects a net peak load of 5,950 megawatts and is planning a reserve of 714 megawatts (DIRS 103413-NPC 1997, Figures 2 and 4). The maximum 54-megawatt demand that the repository would require would be less than 1 percent of the projected peak demand in 2010, and less than 8 percent of the planned reserve. While the accuracy and viability of long-term planning for electrical power demand is now more uncertain than in previous years, DOE expects that regional capacity planning would accommodate the future repository demand.

Repository Electric Power Supply Options

As discussed above, the estimated repository electric power demand would exceed the current electric distribution capacity to the site after construction began in 2005. DOE would have to increase the electric power capacity to the site to accommodate the initial demand of about 25 megawatts during the construction phase and to support the estimated peak demand of as much as 54 megawatts during the operations period. A range of options including a modification or upgrade of the existing transmission and distribution system is under consideration to meet the repository electricity demand (DIRS 102045-CRWMS M&O 1998, all). DOE eliminated consideration of onsite generation of electricity in conjunction with the onsite plant that would generate steam for heating because the steam plant would be much smaller than a plant needed for power generation. DOE would, however, construct and operate a solar power generating facility close to the North Portal to support repository operations. The solar facility, which could produce as much as 3 megawatts of power, would be a dual-purpose facility, serving as a demonstration of photovoltaic power generation and augmenting the overall repository electric power supply (as much as 7 percent). In addition, DOE would also investigate using power supplied from a 436-megawatt wind farm proposed for the Nevada Test Site. This private-sector enterprise is currently being evaluated and has been described in a recent draft environmental assessment (DIRS 154545-DOE 2001, all). DOE has issued a Notice of Intent to prepare an environmental impact statement for this project (66 *FR* 38650; July 25, 2001). Other onsite generation capacity would use diesel-powered generators for emergency equipment.

As discussed in Chapter 3, Section 3.1.11.2, the repository site receives electricity through a feeder line from the Canyon Substation, which is rated at 69 kilovolts and has a capacity of 10 megawatts. The minimum modification would be to upgrade this line to 40 to 54 megawatts, modify the Nevada Test Site power loop to support repository operations in conjunction with other Test Site activities, and upgrade utility feeder lines to the Nevada Test Site. The existing Nevada Test Site power loop has a rated capacity of about 72 megawatts, but preliminary analysis of loop performance with a typical repository load (about 40 megawatts) indicated that unacceptable voltage reductions could occur at some Test Site locations. The minimum modification to the power loop to reduce the potential for unacceptable voltage reductions would be to install capacitors in the loop. Other options to obtain satisfactory performance for the power loop would include upgrading sections of the loop and the utility-owned feeder lines to the loop. Additional options, which would be variations of this approach, would include providing upgraded power lines directly from the utilities to the repository site.

As discussed in Chapter 3, Section 3.1.11.2, two commercial utility companies supply electricity to the Nevada Test Site feeder lines that power the Test Site power loop. Nevada Power Company owns and operates a 138-kilovolt line from the Las Vegas area to the Mercury Switching Station on the Test Site. Valley Electric Association owns and operates 138- and 230-kilovolt lines from the Las Vegas area to Pahrump and a 138-kilovolt line from Pahrump to the Jackass Flats substation on the Test Site near Amargosa Valley. The options DOE is evaluating include upgrading either or both of these lines. The options also include connecting both utility feeder lines directly to the repository with new 138- or 230-kilovolt lines to either the North or South Portal to obtain independent redundant power capability. DOE has considered constructing a new power line from the Tonopah/Anaconda area to near the Town of Amargosa Valley through Beatty with a direct tie to the South Portal at the repository. All system modifications would include appropriate modifications to transformers and switchgear. The approach in all cases would be to use existing power corridors where possible to limit environmental impacts and to reduce the need for additional rights-of-way. Depending on the option chosen, National Environmental Policy Act analysis would be conducted, as appropriate.

Fossil Fuels

Fossil fuels used during the construction phase would include diesel fuel and fuel oil. Diesel fuel would be used primarily to operate surface construction equipment and equipment to maintain the excavated rock pile. Fuel oil would fire a steam plant at the North Portal, which would provide building and process heat for the North Portal Operations Area. During construction the estimated use of diesel fuel and fuel oil would be 5.5 million to 6.0 million liters (1.5 million to 1.6 million gallons). The regional supply capacity of gasoline and diesel fuel is about 3.8 billion liters (1 billion gallons) per year for the State of Nevada, based on motor fuel use (DIRS 148094-BTS 1997, all). About half of the State total is consumed in the three-county region of influence (Clark, Lincoln, and Nye Counties) with the highest consumption in Clark County, so yearly repository use during the construction phase would be less than 1 percent of the current regional consumption.

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Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It would range between about 370 million and 500 million liters (about 98 million and 130 million gallons) depending on the repository operating mode. The annual use would be highest during the operations period and would decrease substantially during the monitoring period. The projected use of liquid fossil fuels would be within the regional supply capacity and would cause little impact. As discussed above, motor fuel use in the State of Nevada in 1996 was about 3.8 billion liters (1 billion gallons) (DIRS 148094-BTS 1997, all), which provides the baseline for the regional supply capacity. The highest annual use during the operations period would be less than 0.5 percent of the 1996 capacity in Clark, Lincoln, and Nye Counties.

During the closure phase, fossil-fuel use would be between 5.1 million and 6.6 million liters (1.3 million and 1.7 million gallons), depending on the repository operating mode. Use during the closure phase would be similar to that for the construction phase.

Hydraulic oils and lubricants and non-fuel hydrocarbons would be used to support operation of equipment during all phases of the project. The quantities of these materials used would range from about 20 million to about 70 million liters (5.3 and 18 million gallons). Because these materials would be recycled and reused, they are not considered in terms of impacts to the environment.

Construction Material

The primary materials needed to construct the repository would be concrete, steel, and copper. Concrete, which consists of cement, sand, aggregate and water, would be used for liners in the main tunnels and ventilation shafts in the subsurface and for the construction of the surface facilities. Aggregate available in the region would be used for concrete and cement would be purchased regionally. The amounts of concrete and cement required are listed in Table 4-39. During the construction phase the amount of concrete required would range from about 420,000 to 500,000 cubic meters (about 550,000 to 650,000 cubic yards), depending on the repository operating mode. For this phase, as much as about 120,000 metric tons (130,000 tons) of steel would be required for a variety of uses including rebar, piping, vent ducts, and track, and 200 to 230 metric tons (220 to 250 tons) of copper for electrical cables. Because the subsurface configuration of the repository would differ for the different operating modes, the relative amount of material used during the initial 5-year construction phase might not be indicative of the amount required to complete the subsurface through the end of development. For example, the amount of steel used during the construction phase for the range of operating modes would be about the same, but the total amount of steel used for the lower-temperature operating mode would be almost twice the amount that would be used for the higher-temperature operating mode.

For the lower-temperature operating mode, which would require the most concrete, the average yearly concrete demand for the construction phase would be about 100,000 cubic meters (about 130,000 cubic yards). The required quantity of concrete would not be expected to affect the regional supply system, which has been able to support the robust construction environment in Las Vegas. The quantities of cement required for the concrete are listed in Table 4-39 because this material would be purchased through regional markets and trucked to the site. This quantity of cement represents less than about 3 percent of the cement consumed in Nevada in 1998 (DIRS 104926-Bauhaus 1998, all).

Because the markets for steel and copper are worldwide in scope, DOE expects little or no impact from increased demand for steel and copper in the region.

The closure phase would require an estimated maximum of 5,000 cubic meters (6,500 cubic yards) of concrete and an estimated maximum of 40 metric tons (44 tons) of steel.

Overall Comparative Impacts

The overall impacts of the repository project in the areas of utilities, energy, and construction material can be compared by evaluating the quantities of these commodities that would be consumed over the life of the project. In general, the quantities of utilities, energy, and materials consumed over the life of the project would be small in comparison to the regional supply capacity, and would be unlikely to affect regional supplies or prices. A major reason for low impacts is the proposed repository schedule for most activities would extend over decades. Even though DOE would build a solar power generating facility on the repository site, it would be necessary to upgrade the transmission lines to the site for the repository to obtain adequate electric power for all the scenarios considered.

Site Services

During the construction phase, DOE would rely on the existing support infrastructure described in Chapter 3, Section 3.1.11.3, during an emergency at the repository. DOE would maintain these capabilities until the project could provide its own services on the site.

The primary onsite response would occur through the onsite Fire Station, Medical Center, and Health Physics facilities after their construction at the North Portal was complete. The Fire Station would maintain fire and rescue vehicles, equipment, and trained professionals to respond to fires, including radiological, mining, industrial, and accident events at the surface and subsurface. The Medical Center would be adjacent to the Fire Station, and would maintain a full-time doctor and nurse and medical supplies to treat emergency injuries and illnesses. These facilities would have the capability to provide complete response to most onsite emergencies. DOE would coordinate the operation of these facilities with facilities at the Nevada Test Site and in the surrounding area to increase response capability, if necessary.

A site security and safeguards system would include the surveillance and safeguards functions required to protect the repository from unauthorized intrusion and sabotage. The system would include the site security barriers, gates, and badging and automated surveillance systems operated by trained security officers. Support for repository security would be available from the Nevada Test Site security force and the Nye County Sheriff's Department, if needed.

The emergency response system would provide responses to accident conditions at or near the repository site. The system would maintain emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground.

The planned onsite emergency facilities should be able to respond to and mitigate most onsite incidents, including underground incidents, without outside support. Therefore, there would be no meaningful impact to the emergency facilities of surrounding communities or counties.

4.1.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

This section describes the management of the radioactive and nonradioactive waste that DOE would generate as a result of performance confirmation, construction, operation and monitoring, and closure activities. The range of operating modes would generate different quantities of waste.

The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, mixed, and radioactive wastes that repository-related activities would generate. Estimated waste quantities are presented in Tables 4-40 through 4-44 in Sections 4.1.12.2 and 4.1.12.4. These estimates were based on construction and operating experience, engineering data, water use estimates, material use estimates, and number of workers. The evaluation assessed these quantities against current public and private capacity to treat and dispose of wastes.

4.1.12.1 Waste and Materials Impacts from Preconstruction Testing and Performance Confirmation

DOE expects preconstruction testing and performance confirmation activities to generate waste similar to and in about the same quantities as that generated during characterization activities with the exception that low-level radioactive waste would be generated in minimal quantities (DIRS 104508-CRWMS M&O 1999, p. 17). Based on 1997 waste generation reports, preconstruction testing and performance confirmation activities should produce about 3,200 cubic meters (110,000 cubic feet) of nonhazardous construction debris and sanitary and industrial solid waste (DIRS 104952-Sygitowicz 1998, pp. 2 and 4) and about 170 kilograms (380 pounds) (volume measurements were not available) of hazardous waste (DIRS 104882-Harris 1998, pp. 3 through 6) that would require disposal. In addition, other waste would be recycled rather than disposed. Wastewater would be generated from runoff, subsurface activities, restrooms, and change rooms.

WASTE TYPES

Construction/demolition debris: Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include such materials as soil, rock, masonry materials, and lumber.

Industrial wastewater: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression, rinsewater from concrete production and transport, and process water from building heating, ventilation, and air conditioning systems.

Low-level radioactive waste: Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. The repository low-level radioactive waste would include such wastes as personal protective clothing, air filters, solids from the liquid low-level radioactive waste treatment process, radiological control and survey waste, and possibly used canisters (dual-purpose).

Sanitary sewage: Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

Sanitary and industrial solid waste: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as *household waste*.

Hazardous waste: Waste designated as hazardous by the Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

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DOE would use current (as described in Chapter 3, Section 3.1.12) or similar methods to handle the waste streams generated by its preconstruction testing and performance confirmation activities. It would also use offsite landfills to dispose of solid waste and construction debris; accumulate and consolidate hazardous waste and transport it off the site for treatment and disposal; treat and reuse wastewater; and treat and dispose of sanitary sewage. Based on site characterization experience, these activities would result in only small impacts to the regional waste disposal capacity.

4.1.12.2 Waste and Materials Impacts from Construction, Operation and Monitoring, and Closure

The construction phase would generate nonhazardous, nonradioactive wastes and some hazardous waste from the use of such materials as resins, paints, and solvents. Nonhazardous, nonradioactive wastes would include sanitary and industrial solid wastes, construction debris, industrial wastewater, and sanitary sewage. Table 4-40 lists the estimated quantities of waste that the construction phase would generate. These estimates are based on construction experience, water use estimates, and Yucca Mountain Site Characterization Project experience with wastewater generation from dust suppression.

Table 4-40. Waste quantities generated during the construction phase.

Waste type	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Construction debris (cubic meters)[a]	5,000	5,000 - 9,300
Hazardous (cubic meters)	1,200	1,200 - 2,300
Sanitary and industrial solid (cubic meters)	11,000	12,000
Sanitary sewage (million liters)[b]	180	180
Industrial wastewater (million liters)	46	55 - 59

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. However, as part of the Proposed Action, DOE would construct a State-permitted landfill on the Yucca Mountain site to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. Section 2.1.2.1.4.3 describes the landfill. If the repository generates construction and demolition debris and sanitary and industrial waste beyond the capacity of this landfill, the excess nonhazardous waste would be disposed of at Nevada Test Site landfills. As listed in Table 4-40, DOE estimates a maximum of 9,300 cubic meters (330,000 cubic feet) of construction debris. If the Department chose not to build a landfill at the repository site, it could ship construction debris to the Test Site's Area 9 U10C Landfill, which has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37). The disposal of construction debris generated during the construction phase would consume less than 1 percent of the disposal capacity in this landfill. DOE could also ship repository-generated sanitary and industrial solid waste to the Test Site for disposal in the Area 23 landfill, which has a capacity of 450,000 cubic meters (16 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37). The disposal of the maximum of 12,000 cubic meters (420,000 cubic feet) of sanitary and industrial solid waste generated during the construction phase at the Area 23 landfill would use less than 3 percent of the disposal capacity.

DOE would package hazardous waste and ship it off the site for treatment and disposal. The Department could continue to dispose of such waste in conjunction with the Nevada Test Site, which has contracts with commercial facilities, or could contract separately with the same or another commercial facility. No more than 2,300 cubic meters (81,000 cubic feet) of hazardous waste (see Table 4-40), weighing 2,300 metric tons (2,500 tons), would be generated during the construction phase. By comparison, 44,000 metric tons (48,000 tons) of hazardous waste was managed in Nevada in 1999 (DIRS 156935-EPA 2001, pp. ES-7). Regional capacity for treatment and disposal of hazardous waste is much greater than the quantity that would be generated at Yucca Mountain. For example, the hazardous waste incineration capacity in western states through 2013 has been estimated at seven times the demand for this service (DIRS 103245-EPA 1996, pp. 32, 33, 35, 46, 47, and 50). The landfill capacity for hazardous waste disposal would be about 50 times the demand. Therefore, the impact on regional hazardous waste capacity from repository-generated hazardous waste during the construction phase would be very small.

DOE would treat and dispose of sanitary sewage and industrial wastewater at onsite facilities. Sanitary sewage from the North Portal Operations Area would go to an existing septic system. The Department would install another septic system to dispose of sanitary sewage from the South Portal Development Area. The industrial wastewater from surface facilities would flow to an evaporation pond at the North Portal Operations Area and wastewater from the subsurface would flow to an evaporation pond at the South Portal Development Area. Sludge would accumulate in the North Portal Operations Area evaporation pond so slowly that DOE would not need to remove it before the closure of the pond (DIRS 102599-CRWMS M&O 1998, pp. 65 to 67). The accumulated sludge at the South Portal Development Area evaporation pond, which would consist of mined rock, portland cement, and fine aggregate, would be removed as needed and added to the excavated rock pile (DIRS 104910-Koppenaal 1998, p. 3). In addition, under the lower-temperature operating mode with surface aging, DOE would install a small evaporation pond for rinsewater from the concrete batch plant as needed.

Activities during the operation and monitoring phase would generate radioactive and nonradioactive wastes and wastewaters and some hazardous waste. DOE does not expect to generate mixed waste. However, repository facilities would have the capability to package and temporarily store mixed waste that operations could generate under unusual circumstances. In addition, the medical clinic would generate a small amount of medical waste that DOE would dispose of in accordance with applicable Federal and State of Nevada requirements. Table 4-41 lists the estimated total waste quantities for repository activities associated with the operation and monitoring phase. These estimates do not include used solar panels because DOE anticipates that recycling options would be available by the time the first solar panels would require replacement, about 2030. Solar panel replacement once every 20 years (DIRS 153882-Griffith 2001, p. 8) would generate about 350 metric tons (390 tons) of material for recycling. Replacement would occur 4 to 16 times, depending on the operating mode.

Table 4-41. Waste quantities generated during the operation and monitoring phase.

	Operating mode	
Waste type	Higher-temperature	Lower-temperature
Low-level radioactive (cubic meters)[a]	68,000	68,000 - 91,000
Hazardous (cubic meters)	6,100	5,600 - 6,300
Sanitary and industrial solid (cubic meters)	81,000	91,000 - 150,000
Sanitary sewage(million liters)[b]	1,800	2,100 - 3,200
Industrial wastewater (million liters)	900	850 - 980

a. To convert cubic meters to cubic feet, multiply by 35.314.

b. To convert liters to gallons, multiply by 0.26418.

Major waste-generating activities during the operation and monitoring phase would include the receipt and packaging of spent nuclear fuel and high-level radioactive waste and continued development of subsurface emplacement areas. Differences in nonradioactive waste quantities from subsurface activities would be due to the different workforce sizes, main drift lengths, and emplacement spacing. Operating mode differences would affect the volumes of hazardous and low-level radioactive wastes generated at the surface facilities as a result of differences in handling the spent nuclear fuel and high-level radioactive waste, and of phase length if waste was aged on the surface. In addition, waste would be generated in personnel areas such as change rooms, restrooms, and offices. If dual-purpose canisters were used and not recycled, the low-level radioactive waste from the canisters would amount to an estimated 29,000 cubic meters (1,000,000 cubic feet) with an estimated weight of 150,000 metric tons (170,000 tons).

However, the total amount of low-level radioactive waste expected using dual-purpose canisters even with the canisters being disposed of rather than recycled would not exceed the amount listed in Table 4-41, which represents the amount expected from the receipt of uncanistered spent nuclear fuel. DOE could decide to recycle the canisters if doing so would be more protective of the environment and more cost effective than direct disposal. Recycling would require melting and recasting of the canister metal to enable other uses.

Monitoring and maintenance activities after the completion of emplacement would also generate wastes, but in much smaller quantities. The first few years after the completion of emplacement would generate greater quantities of waste due to the decontamination and decommissioning of surface nuclear facilities. DOE estimates as much as 700 cubic meters (25,000 cubic feet) of low-level radioactive waste and as much as 280 cubic meters (9,900 cubic feet) of hazardous waste from this activity.

Monitoring and maintenance activities for 76 years under the higher-temperature operating mode would generate a maximum of about 20,000 cubic meters (710,000 cubic feet) of sanitary and industrial solid waste and about 430 million liters (110 million gallons) of sanitary sewage. Monitoring and maintenance activities for 300 years under the lower-temperature operating mode would generate a maximum of about 84,000 cubic meters (about 2.9 million cubic feet) of sanitary and industrial solid waste and about 1.8 billion liters (480 million gallons) of sanitary sewage. Monitoring for periods bounded by these timeframes would generate the same wastes in proportional quantities.

DOE would treat low-level radioactive waste in the Waste Treatment Building (see Section 2.1.2.1.1.3). After treatment, DOE would need to dispose of an estimated maximum 91,000 cubic meters (3.2 million cubic feet) of low-level radioactive waste generated during emplacement activities and the decontamination of surface nuclear facilities. This waste would be disposed of at the Nevada Test Site. The Test Site accepts low-level radioactive waste for disposal from other DOE sites. It has an estimated total disposal capacity of 3.7 million cubic meters (130 million cubic feet) (DIRS 155856-DOE 2000, Table 4-1) (see Section 3.1.12). The reserve capacity (the total capacity reduced by the volume projected to be needed for disposal of other DOE low-level radioactive waste) is 2.6 million cubic meters (92 million cubic feet) (DIRS 155856-DOE 2000, Table 4-1). The impact to the reserve capacity at the Nevada Test Site from the disposal of repository low-level radioactive waste would be 3.5 percent.

During the operation and monitoring phase DOE would dispose of sanitary sewage and industrial wastewater in the onsite wastewater systems and sanitary and industrial solid waste in the onsite landfill or at the Nevada Test Site. The sanitary sewage disposal system would be able to handle the estimated daily sewage flows, and the industrial wastewater facilities would be able to handle the estimated annual wastewater flows. DOE would use the onsite landfill to dispose of sanitary and industrial solid waste, or it could use the existing Nevada Test Site landfill in Area 23 to dispose of such waste. The Area 23 landfill has an estimated 100-year capacity for the disposal of waste generated at the Test Site (DIRS 101803-DOE 1995, p. 9); the addition of repository-generated waste during the operation and monitoring phase would necessitate its expansion.

During the operation and monitoring phase repository-generated hazardous waste would be shipped off the site for treatment and disposal in a permitted facility. DOE would need to dispose of an estimated maximum of 6,300 cubic meters (220,000 cubic feet) of hazardous waste generated by emplacement activities and the decontamination of surface facilities. The estimated maximum annual rate of hazardous waste treatment or disposal would be about 280 cubic meters (9,900 cubic feet), weighing 270 metric tons (300 tons). This peak annual volume is 1 percent of the volume of hazardous waste that was managed in Nevada in 1999. At present, a number of commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. Regional capacity for treatment and disposal of hazardous waste is much greater than the quantity that would be generated at Yucca Mountain. For example, the estimated hazardous waste incineration capacity in western states through 2013 is seven times the demand for this service (DIRS 103245-EPA 1996, pp. 32, 33, 35, 46, 47, and 50). The landfill capacity for hazardous waste disposal would be about 50 times the demand. Therefore, the impact on regional hazardous waste capacity from repository-generated hazardous waste during the operation and monitoring phase would be very small.

If unusual activities generated mixed waste, DOE would package such waste for offsite treatment and disposal. The estimated maximum annual quantity would be about 1.3 cubic meter (46 cubic feet), which would have a very small impact on the receiving facility. At present, there is commercial capacity (for example, at Envirocare of Utah, with which the Department has a contract for the treatment and disposal of mixed waste). DOE is also pursuing a permit for a mixed waste disposal facility at the Nevada Test Site that would accept mixed waste from other DOE sites for disposal. This facility has a planned capacity of 20,000 cubic meters (710,000 cubic feet) (DIRS 155856-DOE 2000, p. 2-32).

Closure activities, such as the final decontamination and demolition of the repository structures and the restoration of the site, would generate waste and recyclable materials. Table 4-42 lists estimated waste quantities for the closure phase. The ranges of quantities result from more waste generated from more years to complete closure and differences in surface facilities.

Table 4-42. Waste quantities generated during the closure phase.

	Operating mode	
Waste type	Higher temperature	Lower temperature
Demolition debris (cubic meters)[a]	220,000	220,000 - 440,000
Hazardous (cubic meters)	1,200	1,100 - 1,200
Sanitary and industrial (cubic meters)	9,500	9,300 - 12,000
Sanitary sewage (million liters)[b]	160	170 - 250
Industrial wastewater (million liters)	70	77 - 120
Low-level radioactive (cubic meters, after treatment)	3,500	3,200 - 4,600

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

DOE would dispose of demolition debris and sanitary and industrial solid waste in the onsite landfill (or at the Nevada Test Site), and sanitary sewage and industrial wastewater in the onsite septic systems and industrial wastewater system. After disposing of the waste and wastewater, DOE would close the landfill and evaporation ponds in a manner that met applicable requirements.

The Nevada Test Site landfills would have to continue operating past their estimated lives and to expand as needed. The Area 9 U10C Landfill, which accepts demolition debris, has an estimated 70-year operational life; the Area 23 landfill, which is used for sanitary and industrial solid waste disposal, has a 100-year estimated life (DIRS 101803-DOE 1995, pp. 8 and 9).

DOE would continue to dispose of hazardous and low-level radioactive wastes off the site. The Department would ship hazardous waste to an offsite vendor with the appropriate permits and available treatment and disposal capacity. The available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50). Therefore, hazardous waste generated during closure activities would be likely to have a very small impact on the capacity for treatment and disposal at commercial facilities. DOE would ship low-level radioactive waste to a Nevada Test Site disposal facility. The disposal of low-level radioactive waste generated during repository closure at the Nevada Test Site would affect the reserve disposal capacity about two-tenths of 1 percent.

Overall Impacts to Waste Management

The overall impact of managing the Yucca Mountain repository waste streams would differ little among the operating modes, in part because DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater. Although such activities are not currently planned, the use of existing Nevada Test Site landfills for the disposal of construction and demolition debris and sanitary and industrial solid waste would require the continuation of the operation of these facilities past their estimated lifetimes of 70 and 100 years (DIRS 101803-DOE 1995, pp. 8 and 9). Such use would probably require the expansion of landfill capacities. Use of the Nevada Test Site U10C landfill for construction and demolition debris would require at least 61 percent of the reserve capacity, and could exceed the disposal capacity by 20 percent if 440,000 cubic meters (16 million cubic feet) was to be disposed at the landfill. Use of the Nevada Test Site Area 23 landfill for sanitary and industrial solid waste disposal would use 23 to 37 percent of the disposal capacity. Further review under the National Environmental Policy Act would be completed, as required, to expand capacity of the landfills at the Nevada Test Site.

Repository-generated low-level radioactive and hazardous waste would have little impact at disposal facilities, which could readily accommodate this waste. DOE would use less than 4 percent of the reserve capacity for low-level radioactive waste disposal at the Nevada Test Site. A very small fraction of the existing offsite capacity would be used for repository-generated hazardous waste. The peak annual volume of hazardous waste would be 1 percent of the volume of hazardous waste managed in Nevada in 1999, when the State ranked fortieth in the Nation for the amount of hazardous waste managed (DIRS 156935-EPA 2001, p. ES-7). Nationally, hazardous waste treatment and disposal facilities received 6.0 million metric tons (6.6 million tons) of hazardous waste in 1999 (DIRS 156935-EPA 2001, p. ES-10). As noted above, the projected available capacity through 2013 for treatment and disposal of hazardous waste greatly exceeds demand. The impact to hazardous waste treatment and disposal capacity from repository-generated hazardous waste would be very small.

Table 4-43 lists waste quantities generated for the higher-temperature operating mode and the range of estimated waste quantities for the lower-temperature operating mode for all phases. If not recycled, dual-purpose canisters would add an estimated 29,000 cubic meters (1,000,000 cubic feet) of low-level waste.

Table 4-43. Total waste quantities generated for all phases.[a]

Waste type	Operating mode: Higher-temperature	Operating mode: Lower-temperature[b]
Construction and demolition debris (cubic meters)[c]	220,000	220,000 - 440,000
Hazardous (cubic meters)	8,400	8,400 - 8,900
Sanitary and industrial solid (cubic meters)	100,000	110,000 - 170,000
Sanitary sewage (million liters)[d]	2,100	2,400 - 3,600
Industrial wastewater (million liters)	1,000	990 - 1,200
Low-level radioactive (cubic meters after treatment)	71,000	71,000 - 95,000

a. Totals for the construction, operation and monitoring, and closure phases.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. To convert liters to gallons, multiply by 0.26418.

4.1.12.3 Impacts from Hazardous Materials

The operation of the Yucca Mountain Repository would require the use of hazardous materials including paints, solvents, adhesives, sodium hydroxide, dry carbon dioxide, aluminum sulfate, sulfuric acid, and compressed gases. DOE has programs and procedures in place to procure and manage hazardous materials (DIRS 104842-YMP 1996, all), ensuring their procurement in the appropriate quantities and storage under the proper conditions. At the repository, DOE would use an automated inventory management program (DIRS 104508-CRWMS M&O 1999, p. 62) to control and track inventory.

4.1.12.4 Waste Minimization and Pollution Prevention

DOE would develop a waste minimization and pollution prevention awareness plan similar to the plan it has used during site characterization activities at Yucca Mountain (DIRS 103203-YMP 1997, all). The goal of this new plan would be to minimize quantities of generated waste and to prevent pollution. To achieve this goal, DOE would establish requirements for each onsite organization and identify methods and activities to reduce waste quantities and toxicity.

DOE would recycle materials to the extent that it was cost-effective, feasible, and environmentally sound. Table 4-44 lists estimated quantities of materials that DOE would recycle during the life of the repository.

Table 4-44. Total recyclable material quantities generated for all phases.[a]

	Operating mode	
Material	Higher-temperature	Lower-temperature[b]
Recyclables (cubic meters)[c,d]	230,000	260,000 - 370,000
Steel (metric tons)[e]	51,000	51,000 - 240,000
Dual-purpose canisters[f] (cubic meters)	29,000	29,000
Oils and lubricants (liters)[g]	22 million	34 million - 67 million
Solar panels (metric tons)	1,700	1,700 - 5,700

a. Total for construction, operation and monitoring, and closure phases.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. Nonhazardous, nonradioactive materials such as paper, plastic, glass, and nonferrous metals.
d. To convert cubic meters to cubic feet, multiply by 35.314.
e. To convert metric tons to tons, multiply by 1.1023.
f. If dual-purpose canisters were used they would be recycled if appropriate, with regard to protection of the environment and cost-effectiveness. Estimated weight is 150,000 metric tons.
g. To convert liters to gallons, multiply by 0.26418.

DOE has identified pollution prevention opportunities in the repository conceptual design process. The Waste Treatment Building design includes recycling facilities for the large aqueous low-level radioactive waste stream [690,000 liters (182,000 gallons) per year for the uncanistered packaging scenario] (DIRS 100248-CRWMS M&O 1997, p. 23) that would result from decontamination activities. Wastewater recycling would greatly reduce water demand by repository facilities, as well as the amount of wastewater that would otherwise require disposal. In addition, DOE would use practical, state-of-the-art decontamination techniques such as pelletized solid carbon dioxide blasting that would generate less waste than other techniques.

In addition, DOE would use automated maintenance tracking and inventory management programs that would interface with the procurement system (DIRS 104508-CRWMS M&O 1999, p. 62). These systems would assist in ensuring the proper maintenance of equipment through a preventive maintenance approach, which could lead to less waste generation. Inventory management would prevent overstocking that could allow chemicals and other items to exceed their shelf lives and become waste.

4.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address the potential for their activities to cause disproportionately high and adverse impacts to minority or low-income populations. This section uses the results of analyses from other disciplines and consideration of unique exposure pathways, sensitivities, and cultural practices to determine if disproportionately high and adverse impacts to human health or the environment of minority or low-income populations are likely to occur from repository performance confirmation, construction, operation and monitoring, and closure activities.

4.1.13.1 Methodology and Approach

DOE performs environmental justice analyses to identify whether any high and adverse impacts would fall disproportionately on minority and low-income populations. The potential for environmental justice concerns exists if the following could occur:

- *Disproportionately high and adverse human health effects:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. *Disproportionately high and adverse human health effects* occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (DIRS 103162-CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (DIRS 103162-CEQ 1997, all).

The approach to environmental justice analysis first brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that in turn could affect human health or the environment. On the basis of these analyses, DOE identified potential impacts on the general population. Second, based on available information, the approach assesses whether there are unique exposure pathways, sensitivities or cultural practices that would result in different impacts on minority or low-income populations. If potential impacts identified under either assessment would be high and adverse, the approach then compares the impacts on minority and low-income populations to those on the general population to determine whether any high and adverse impacts fall disproportionately on minority and low-income populations. In other words, if high and adverse impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, no disproportionately high and adverse impacts would be expected. In making these determinations, DOE considers geographical areas that contain high percentages of minority or low-income populations as reported by the Bureau of the Census. As discussed in Chapter 3, Section 3.1.13, DOE used 2000 Census data for minority populations and 1990 Census data for low-income populations as the best, readily available information that would allow identification of the minority and low-income populations.

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprised of a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population [for this EIS, a minority population is one in which the percent of the total population comprised of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (DIRS 103162-CEQ 1997, all)]. Nevada had a minority population of 34.8 percent in 2000. For this EIS, therefore, one focus of the environmental justice analysis is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census tracts in the region of influence (principally in Clark, Nye, and Lincoln Counties) having a minority population of 44.8 percent or higher.

Nevada had a low-income population of 10 percent in 1990. Using the approach described in the preceding paragraph for minority populations, a low-income population is one in which 20 percent or more of the persons in a census block group live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements (DIRS 148189-Bureau of the Census 1999, all). Therefore, the second focus of the environmental justice analysis for this EIS is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census block groups having a low-income population of 20 percent or higher.

In response to public comments, DOE has reevaluated available information to determine whether the Draft EIS overlooked any unique exposure pathways or unique resource uses that could create opportunities for disproportionately high and adverse impacts to minority and low-income populations, even though the impacts to the general population would not be high and adverse. Several unique pathways or resources were identified and analyzed, although none revealed a potential for disproportionately high and adverse impacts (see Section 4.1.13.2).

4.1.13.2 Preconstruction Testing and Performance Confirmation, Construction, Operation and Monitoring, and Closure

Cultural Resources

DOE has implemented a worker education program on the protection of these resources to limit direct impacts to cultural resources, especially inadvertent damage and illicit artifact collecting. If significant data recovery (artifact collection) were required during construction and operation, DOE would initiate additional consultations with Native American Tribes to determine appropriate involvement. Further, archaeological resources and potential data recovery would be managed and conducted through consultations with the State Historic Preservation Officer or the Advisory Council on Historic Preservation.

Public Health and Safety

The EIS analyses determined that the impacts that could occur to public health and safety would be small on the population as a whole for all phases of the Proposed Action, and that no subsections of the population, including minority or low-income populations, would receive disproportionate impacts. The analysis considered an area that included Timbisha Shoshone Trust lands near Scottys Junction, Nevada.

Because contamination of edible plants and animals would be unlikely from construction, operation and monitoring, and eventual closure of the repository, impacts to persons leading subsistence lifestyles would be unlikely. During the period of construction, operation and monitoring, and closure of the proposed repository, the only radionuclides expected to be released would be naturally occurring radon and radon decay products, and noble gases. Of these, only radon decay products have the potential to accumulate in the environment in the edible portions of wild animals that might live within the land withdrawal area and later be consumed. DOE estimated the potential health impacts from a subsistence diet based primarily on game taken from lands proximate to the repository exclusion areas. DOE calculated the consequences of a 100 kilograms per year (approximately 220 pounds per year or 10 to 11 ounces per day over a year) ingestion of animals that had hypothetically experienced radon uptake. For the peak year, DOE calculated a 0.4 millirem increase in dose, which would have no adverse health effects. DOE concluded that no disproportionately high and adverse health and safety impacts would be likely. DOE also reviewed data on the potential for radioactive uptake from consumption of piñon nuts (DIRS 156058-Fresquez et al. 2000, all). Because piñon pine nuts are produced irregularly in 7- to 10-year cycles and radionuclide concentrations are very low in piñon pine trees and their edible portions, DOE concluded there would be little potential health impact. There would be no disproportionately high and adverse health and safety impacts.

Land Use

Direct land-use impacts from the Proposed Action would be low on members of the public because of the existing restriction on site access for most affected areas. There are no communities with high percentages of minority or low-income populations within the region of influence (see Chapter 3, Table 3-1).

Air Quality

Impacts to air quality from the Proposed Action would be small. Furthermore, DOE would use best management practices for all activities, particularly ground-disturbing activities that could generate fugitive dust and construction activities that could produce vehicle emissions. The analysis considered an area that included Timbisha Shoshone Trust lands near Scottys Junction, Nevada.

Biological Resources and Soils

Impacts to biological resources and soils would be low to nonexistent. Consequences for any resources of importance to minority or low-income communities would be small.

Socioeconomics

Because of the large population and employment in the region of influence, socioeconomic impacts from repository construction and operation would be small. During the construction phase and the operation and monitoring phase, regional employment would increase less than 0.5 percent above the baseline level (see Section 4.1.6.2.1). Changes to the baseline regional population would not be greater than 0.5 percent through 2033. The Proposed Action would generate minimal impacts to employment and population. Potential socioeconomic impacts of all other economic parameters analyzed (Gross Regional Product, real disposable income, and expenditures by State and local governments) would be small.

Noise

Impacts to sensitive noise receptors from the Proposed Action would not be likely because no sensitive noise receptors live in the Yucca Mountain region. Furthermore, there are no low-income or minority communities adjacent to the site.

4.1.13.3 Environmental Justice Impact Analysis Results

This analysis uses information from Sections 4.1.1 through 4.1.12. Those sections address impacts from all active phases of the Proposed Action—construction, operation and monitoring, and closure. As noted above, DOE expects that the impacts of the Proposed Action would be small on the population as a whole. DOE has not identified any subsection of the population, including minority and low-income populations, that would receive disproportionate impacts, and no unique exposure pathways, sensitivities, or cultural practices that would expose minority or low-income populations to disproportionately high and adverse impacts. Accordingly, DOE has concluded that no disproportionately high and adverse impacts would result from the Proposed Action.

4.1.13.4 A Native American Perspective

Native American tribal governments have a special and unique legal and political relationship with the Government of the United States, as established by treaty, statute, legal precedent, and the U.S. Constitution. For this reason DOE will continue to consult with tribal governments and will continue to work with representatives of the Consolidated Group of Tribes and Organizations to ensure the consideration of tribal rights and concerns before making decisions or implementing programs that affect such tribes; to continue the protection of Native American cultural resources, sacred sites, and potential traditional cultural properties; and to implement any appropriate mitigation measures.

In reaching the conclusion that there would be no disproportionately high and adverse impacts on minorities or low-income populations, DOE acknowledges that people from many Native American tribes have used the area proposed for the repository as well as nearby lands (DIRS 102043-AIWS 1998, p. 2-1), that the lands around the site contain cultural, animal, and plant resources important to those tribes, and that the implementation of the Proposed Action would continue restrictions on free access to the repository site. DOE acknowledges that Native American people living in the Yucca Mountain vicinity have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action.

Native American people living in the Yucca Mountain vicinity hold views and beliefs about the relationship between the proposed repository and the surrounding region that they have expressed in *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all). Concerning the approach to daily life, the authors of that document, who represent the Western Shoshone, Owens Valley Paiute and Shoshone, Southern Paiute, and other Native American organizations, state:

> *…we have the responsibility to protect with care and teach the young the relationship of the existence of a nondestructive life on Mother Earth. This belief is the foundation for our holistic view of the cultural resources, i.e., water, animals, plants, air, geology, sacred sites, traditional cultural properties, and artifacts. Everything is considered to be interrelated and dependent on each other to sustain existence (DIRS 102043-AIWS 1998, p. 2-9).*

The authors discuss the cultural significance of Yucca Mountain lands to Native American people:

> *American Indian people who belong to the CGTO (Consolidated Group of Tribes and Organizations) consider the YMP lands to be as central to their lives today as they have been since the creation of their people. The YMP lands are part of the holy lands of Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone people (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *The lack of an abundance of artifacts and archaeological remains does not infer that the site was not used historically or presently and considered an integral part of the cultural ecosystem and landscape (DIRS 102043-AIWS 1998, p. 2-10).*

The authors address the continuing denial of access to Yucca Mountain lands:

> *One of the most detrimental consequences to the survival of American Indian culture, religion, and society has been the denial of free access to their traditional lands and resources (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *No other people have experienced similar cultural survival impacts due to lack of free access to the YMP area (DIRS 102043-AIWS 1998, p. 2-20).*

The authors recognize that past restrictions on access have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (DIRS

102043-AIWS 1998, Section 3.1.1). However, the authors express concerns of Native American people regarding use of the repository:

> *The past, present, and future pollution of these holy lands constitutes both Environmental Justice and equity violations. No other people have had their holy lands impacted by YMP-related activities (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *Access to culturally significant spiritual places and use of animals, plants, water and lands may cease because Indian people's perception of health and spiritual risks will increase if a repository is constructed (DIRS 102043-AIWS 1998, p. 3-1).*

Even after closure and reclamation, the presence of the repository would represent an irreversible impact to traditional lands and other elements of the natural environment in the view of Native American people.

Regarding the transportation of spent nuclear fuel and high-level radioactive waste, the authors state:

> *…health risks and environmental effects resulting from the construction and operation of the proposed intermodal transfer facility (ITF) and the transportation of high-level waste and spent nuclear fuel is considered by Indian people to be disproportionately high. This is attributed primarily to the consumption patterns of Indian people who still use these plants and animals for food, medicine, and other related cultural or ceremonial purposes (DIRS 102043-AIWS 1998, p. 2-19).*

and:

> *The anticipated additional noise and interference associated with an ITF* [Intermodal Transfer Facility] *and increased transportation may disrupt important ceremonies that help the plants, animals, and other important cultural resources flourish, or may negatively impact the solitude that is needed for healing or praying (DIRS 102043-AIWS 1998, p. 2-19).*

DOE recognizes that it could not undertake disposal of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain without conflict with the viewpoint expressed in the American Indian Writers Subgroup document, but believes that, should the repository be designated, DOE would have the opportunity to engage in regular consultations with representatives of tribes in the region to identify further measures to protect cultural resources, thereby lessening the concern expressed by Native American people.

4.1.14 IMPACTS OF REPOSITORY OPERATING MODES

This section briefly describes and compares the short-term environmental impacts for the range of repository operating modes considered as part of the Proposed Action. This range includes the higher-temperature operating mode [where postclosure repository temperatures could be above the boiling point of water (96°C, or 205°F) and the lower-temperature operating mode [where postclosure repository temperatures would remain below 85°C (185°F)]. The lower-temperature operating mode also includes a range of operating characteristics, and differences noted below describe the largest potential differences among the operating modes.

In general, the EIS analyses found the lower-temperature operating mode would have higher environmental impacts than the higher-temperature operating mode. At least partly responsible for this is the fact that the duration of the lower-temperature operating mode (171 to 341 years) would be longer than the duration of the higher-temperature operating mode (115 years). Any time-dependent impacts, such as health and safety impacts to populations or energy or material usage, are typically higher for the longer duration lower-temperature operating mode. Overall, impacts would be small. Some areas of specific interest:

- Short-term health and safety impacts to the public would be small, with those of the lower-temperature operating mode 2 to 4 times greater than the higher-temperature operating mode.
- Short-term health and safety impacts to workers would be small, with those of the lower-temperature operating mode up to 60 to 70 percent greater than the higher-temperature operating mode.
- Short-term impacts for the land use, ambient air quality, surface water, groundwater, biological resources and soil, cultural resources, socioeconomics, repository accidents, noise, aesthetics, utilities, energy, materials, waste generation, and environmental justice would be small.

A more complete comparison of potential impacts is shown in Section 2.4 and Table 2-7.

4.1.15 IMPACTS FROM MANUFACTURING REPOSITORY COMPONENTS

This section discusses the potential environmental impacts from the manufacturing of components required by the Proposed Action to dispose of spent nuclear fuel and high-level radioactive waste permanently at a monitored geologic repository at Yucca Mountain. Repository components include disposal containers, emplacement pallets, drip shields, dry storage cask shells, and shipping casks. The solar panels required for the solar power electric generating facility are standard commercially available components that DOE could buy from several vendors. Therefore, there would be no offsite manufacturing environmental impacts specifically attributed to the solar panels. This analysis considers transportation overpacks that would provide radiation shielding in the same manner as a shipping cask but that DOE would use only in conjunction with disposable canisters and dual-purpose canisters to be shipping casks without baskets or other internal configurations.

4.1.15.1 Overview

DOE followed the overall approach and analytical methods used for the environmental evaluation and the baseline data directly from the *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel* (DIRS 101941-USN 1996, all). DOE's evaluation focuses on ways in which the manufacture of the repository components could affect environmental attributes and resources at a representative manufacturing site. It is not site-specific because more than one manufacturer probably would be required to meet the production schedule requirements for component delivery, and the location of the companies chosen to manufacture these components is not known. The companies and, therefore, the actual manufacturing sites would be determined by competitive bidding.

The analysis used a representative manufacturing site based on five facilities that produce casks, canisters, and related hardware for the management of spent nuclear fuel. The concept of a representative site was used in the Navy EIS (DIRS 101941-USN 1996, p. 4-1), and the representative site used in this analysis was defined in the same way, using the same five existing manufacturing facilities with the same attributes. The facilities used to define the representative site are in Westminster, Massachusetts; Greensboro, North Carolina; Akron, Ohio; York, Pennsylvania; and Chattanooga, Tennessee (DIRS 101941-USN 1996, p. 4-17). All of these facilities make components for firms with cask and canister designs approved by the Nuclear Regulatory Commission.

The analysis assumed that the manufacturing facilities and processes being used are similar to the facilities and processes that would produce disposal containers, emplacement pallets, drip shields, dry storage cask shells, and shipping casks for the Yucca Mountain Repository. Although these five facilities

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might not fabricate components from titanium (the material required for the drip shields), the fabrication processes of rolling plate, forming, and welding necessary to produce a drip shield are similar to the processes used to manufacture casks and canisters from other structural material. The estimates for manufacturing time and component cost account for the differences in processing titanium components (for example, welding), so the impacts of manufacturing titanium components could be estimated using the same methods as those used for standard nuclear-grade components. The analysis considered the manufacturing processes used at these facilities and the total number of components required to implement each packaging scenario. Manufacture of all components was assumed to occur at one representative site, but DOE recognizes that it probably would occur at more than one site. The assumption of one manufacturing site is conservative (that is, it tends to overestimate impacts) because it concentrates the potential impacts.

In addition, the analysis of offsite manufacturing evaluated the use of materials and the potential for impacts to material markets and supplies.

Section 4.1.15.3 describes the components to be manufactured offsite. Section 4.1.15.4 discusses pertinent information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 describes environmental impacts on air quality, health and safety, socioeconomics, material use, waste generation, and environmental justice.

4.1.15.2 Components and Production Schedule

Table 4-45 lists the quantities of components analyzed for the higher- and lower-temperature operating modes for canistered and uncanistered packaging scenarios described in Chapter 2, Section 2.1.1. In general, the environmental impacts of offsite manufacturing are bounded by the uncanistered packaging scenario. The impacts of the canistered scenario are also presented to allow canistered and uncanistered comparisons. The only component with higher quantities under canistered scenarios would be rail shipping casks. Table 4-45 includes all repository components for naval spent nuclear fuel that would be emplaced in Yucca Mountain but does not include shipping casks for naval spent nuclear fuel. Shipping casks for naval spent nuclear fuel are owned and managed by the Navy. DIRS 101941-USN (1996, all) analyzed environmental impacts for production of naval spent nuclear fuel canisters and shipping casks. Because naval spent nuclear fuel waste packages represent less than 3 percent of the inventory to be emplaced in the repository, the production of naval spent nuclear fuel casks would add little to the impacts described in the following sections.

Table 4-45. Quantities of offsite-manufactured components for the Yucca Mountain Repository.[a]

		Operating mode/packaging scenario[b]			
		Higher-temperature		Lower-temperature	
Component	Description	UC	C	UC	C
Rail shipping casks or overpacks	Storage and shipment of SNF[c] and HLW[c]	0	92 or 120	0	92 or 120
Legal-weight truck shipping casks	Storage and shipment of uncanistered fuel	120	8	120	8
Disposal containers		11,300	11,300	11,300 - 16,900	11,300 - 16,900
Emplacement pallet	Support for emplaced waste package	11,300	11,300	11,300 - 16,900	11,300 - 16,900
Drip shields	Titanium cover for a waste package	10,500	10,500	11,300 - 15,900	11,300 - 15,900
Solar panels[d]	Photovoltaic solar panels–commercial units	27,000	27,000	27,000	27,000
Dry storage cask shells[e]	Metal shell structure of storage vault for aging	0	0	0 - 4,000	0 - 4,000

a. The number of containers is an approximation but is based on the best available estimates.
b. UC = uncanistered; C = canistered.
c. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
d. Number of panels in use at any one time.
e. Necessary only for commercial spent nuclear fuel and only if DOE used surface aging as part of a lower-temperature operating mode.

As currently planned, all of the components listed in Table 4-45 except drip shields would be manufactured over 24 years to support emplacement in the repository. Manufacturing activity would build up during the first 5 years, then would remain nearly constant through the remainder of the 24-year period. The drip shields would not be needed until the closure of the repository; therefore, the analysis assumed manufacture and delivery of drip shields would not begin until nearly 76 to 300 years after the completion of emplacement. It would take approximately 10 years to manufacture drip shields. The solar power generating facility would be built over a 6-year period beginning in 2005 (DIRS 153882-Griffith 2001, p. 6).

The dry storage cask shells would be needed only if surface aging were to be used in conjunction with the lower-temperature operating mode. Because surface aging would occur in parallel with emplacement, the dry storage cask shells would be manufactured in the same 24-year period as the disposal containers, emplacement pallets, and shipping casks.

4.1.15.3 Components

Disposal Containers

The disposal container would be the final outside container used to package the spent nuclear fuel and high-level radioactive waste emplaced in the repository. The basic design calls for a cylindrical vessel with an outer layer of corrosion-resistant nickel-based alloy (Alloy-22) and an inner liner of stainless steel Type 316NG. The inner and outer lids would be stainless steel Type 316NG and Alloy-22, respectively. An additional Alloy-22 lid would be installed on the closure end. The bottom lids would be welded to the cylindrical body at the fabrication shop, and the top inner and outer lids would be welded in place after the placement of spent nuclear fuel or high-level radioactive waste in the container at the repository. About 10 different disposal container designs would be used for different types of spent nuclear fuel and high-level radioactive waste. The designs would vary in length from 3.6 to 6.1 meters (11.8 to 20 feet) and the outside diameters would range from 1.3 to 2.1 meters (4.3 to 6.6 feet). In addition, the internal configurations of the containers would be different to accommodate different uncanistered spent nuclear fuel configurations and a variety of spent nuclear fuel and high-level radioactive waste disposable canisters. The mass of an empty disposal container would range from about 19 to 33 metric tons (21 to 36 tons). If surface aging was used as part of the lower-temperature operating mode, containers used for aging are assumed to be stainless steel Type 316NG.

Casks for Rail and Legal-Weight Truck Shipments

DOE would use two basic kinds of shipping cask designs—rail and truck—to ship spent nuclear fuel and high-level radioactive waste to the repository. The design of a specific cask would be tailored to the type of material it would contain. For example, rail and truck casks that could be used to ship commercial spent nuclear fuel would be constructed of stainless- or carbon-steel plate materials formed into cylinders and assembled to form inner and outer cylinders (DIRS 101941-USN 1996, p. 4-3 and 4-4). A depleted uranium or lead liner would be installed between the stainless- or carbon-steel cylinders, and a vessel bottom with lead or depleted uranium between the inner and outer stainless- or carbon-steel plates would be welded to the cylinders. A support structure that could contain neutron-absorbing material would be welded into the inner liner, if required. A polypropylene sheath would be placed around the outside of the cylinder for neutron shielding. After spent nuclear fuel assemblies were inserted into the cask, a cover with lead or depleted uranium shielding would be bolted to the top of the cylinder to close and seal it. Transportation overpacks would be very similar in design and construction to shipping casks but would not have an internal support structure for the spent nuclear fuel because they would be used only for dual-purpose or disposable canisters.

For commercial spent nuclear fuel, casks and overpacks are typically 4.5 to 6 meters (15 to 20 feet) long and about 0.5 to 2 meters (1.6 to 6.6 feet) in diameter. These casks are designed to be horizontal when shipped. Empty truck casks typically weigh from 21 to 22 metric tons (about 23 to 24 tons). Empty rail casks (or overpacks) for commercial spent nuclear fuel typically weigh from 59 to 91 metric tons (65 tons to a little over 100 tons). The corresponding weights when loaded with spent nuclear fuel range between 22 and 24 metric tons (24 and 26 tons) for truck casks and between 64 and 110 metric tons (70 and 120 tons) for rail casks. For protection during shipment, large removable impact limiters of aluminum honeycomb or other crushable impact-absorbing material would be placed over the ends (DIRS 101837-JAI 1996, all).

Emplacement Pallets

The emplacement pallet would support the waste packages emplaced and allow end-to-end placement of waste packages to within 10 centimeters (4 inches) of each other. The emplacement pallet would be shorter than the waste package so it would not interfere with close placement. The pallets would be fabricated from Alloy-22 plates welded together to form a V-shaped top surface, which would accept all waste package diameters, and two Alloy-22 supports. Stainless steel Type 316L tubes would connect the two emplacement Alloy-22 supports. Two pallet overall lengths are specified for emplacement support of all waste package designs. The shorter emplacement pallet [2.5 meters (8 feet)] would be used for the waste package containing DOE spent nuclear fuel and high-level radioactive waste and the longer emplacement pallet [4.2 meters (14 feet)] would be used for all other waste package designs. The mass of a short pallet and a long pallet is 1.8 and 2.1 metric tons (2 and 2.2 tons), respectively.

Drip Shields

The drip shield would be a rigid structure designed to divert water away from the waste packages. The drip shield would be fabricated from titanium Grade 7 plates for the water diversion surface, titanium Grade 24 for the structural members, and Alloy-22 for the feet. The Alloy-22 feet would be mechanically attached to the titanium drip shield side plates, since the two materials cannot be welded together. For the higher-temperature operating mode and the lower-temperature operating modes with waste package spacing of less than 1.6 meters (5 feet), a continuous design drip shield would be used. The continuous design drip shield would be installed in sections, with one end designed to overlap and interlock with the opposite end of the previously emplaced drip shield section. The continuous drip shield section would be 6.1 meters (20 feet) long by 2.5 meters (8 feet) wide by 6.1 meters (20 feet) high with a mass of 4.2 metric tons (4.6 tons).

For the lower-temperature operating mode, as waste package spacing increased it might become economical to use a freestanding enclosed drip shield design (DIRS 152808-Skorska 2000, all). The freestanding drip shield would be designed in two lengths, one shorter version [3.9-meter (13-foot) length] for the waste package containing DOE spent nuclear fuel and high-level radioactive waste and one longer version [6.4-meter (20-foot) length] for all other waste package designs. The ends of these drip shields would be partially enclosed. The materials used for the freestanding drip shield design would be the same as for the continuous design drip shield. The mass of a short drip shield and a long drip shield is 3.1 metric tons (3.4 tons) and 4.55 metric tons (5 tons), respectively.

Dry Storage Cask Shells

The dry storage cask shell would be fabricated from carbon steel. The shell would be the portion of the concrete dry storage cask system (used only for surface aging under the lower-temperature operating mode) that would be manufactured offsite. Each shell, which includes a base structure, would be approximately 3.4 meters (11 feet) in diameter by 5.9 meters (19 feet) high and would be made from thick carbon steel plate. Carbon steel plate would be formed into a cylinder to form the shell and carbon plate material would be welded to the shell cylinder to form the base structure of the shell. The shell would weigh about 44 metric tons (49 tons).

4.1.15.4 Existing Environmental Settings at Manufacturing Facilities

Because there are facilities that could meet the projected manufacturing requirements, the assessment concluded that no new construction would be necessary and that there would be no change in land use for the offsite manufacture of repository components. Similarly, cultural, aesthetic, and scenic resources would remain unaffected. Ecological resources, including wetlands, would not be affected because existing facilities could accommodate the manufacture of repository components and new or expanded facilities would not be required. Some minor increases in noise, traffic, or utilities would be likely, but none of these increases would result in impacts on the local environment.

Water consumption and effluent discharge during the manufacture of components would be typical of a heavy manufacturing facility and would represent only a small change, if any, from existing rates. Similarly, effluent discharges would not increase enough to cause difficulty in complying with applicable local, state, and Federal regulatory limits, and would be unlikely to result in a discernible increase in pollutant activity.

Accordingly, the following paragraphs contain information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 evaluates the environmental impacts to these resource areas for a representative site.

Air Quality

The analysis evaluated the ambient air quality status of the representative manufacturing location by examining the air quality of the areas in which the reference manufacturing facilities are located. The principal criteria pollutants for cask manufacturing facilities are ozone, carbon monoxide, and particulate matter (PM_{10}). Areas where ambient air quality standards are not exceeded, or where measurements have not been made, are considered to be in attainment. Areas where the air quality violates Federal or state regulations are in nonattainment and subject to more stringent regulations. Typical existing container and cask manufacturing facilities are in nonattainment areas for ozone and in attainment areas for carbon monoxide and particulate matter.

Because most of the existing typical manufacturing facilities are in nonattainment areas for ozone, the analysis assumed that the representative site would be in nonattainment for ozone and that ozone would be the criteria pollutant of interest. Volatile organic compounds and nitrous oxides are precursors for ozone and are indicators of likely ozone production. For the areas in which the reference manufacturing facilities are located, an average of 3,400 metric tons (approximately 3,800 tons) of volatile organic compounds and 39,000 metric tons (approximately 43,000 tons) of nitrous oxides were released to the environment in 1990 (DIRS 101941-USN 1996, p. 4-5).

Health and Safety

Data on the number of accidents and fatalities associated with cask and canister fabrication at the representative manufacturing location were based on national incidence rates for the relevant sector of the economy. In 1992, the occupational fatality rate for the sector that includes all manufacturing was 3 per 100,000 workers; the occupational illness and injury rate for fabricated plate work manufacturing in 1992 was 6.3 per 100 full-time workers (DIRS 101941-USN 1996, p. 4-5).

The manufacture of hardware for each of the operating modes and packaging scenarios would be likely to be in facilities that have had years of experience in rolling, shaping, and welding metal forms, and then fabricating large containment vessels similar to the required repository components for nuclear materials. Machining operations at these facilities would involve standard procedures using established metalworking equipment and techniques. Trained personnel familiar with the manufacture of large, multiwall, metal containment vessels would use the equipment necessary to fabricate such items. Because of this experience and training, DOE anticipates that the injury and illness rate would be equal to or lower than the industry rates.

Socioeconomics

Each of the five manufacturing facilities examined in this analysis is in a Metropolitan Statistical Area or a Primary Statistical Area, as defined by the U.S. Bureau of the Census. The counties comprising each statistical area define the affected socioeconomic environment for each facility. The populations of the affected environments associated with the five facilities ranged from about 373,000 to 1.2 million in 1998 (DIRS 156775-Bureau of the Census 2001, p. 33). In 1995, output (the value of goods and services produced in the five locations) ranged from $18 billion to $55 billion. The income (wages, salaries, and property income) ranged from $9 billion to $26 billion, area employment ranged from 245,000 to 670,000 workers in 1995, and plant employment ranged from 25 to 995 (DIRS 101941-USN 1996, p. 4-6). Based on averages of this information, the representative manufacturing location has a population of about 690,000 and the representative plant employs 480. Local output in the area is $30 billion, local income is $15 billion, and local employment is 390,000.

4.1.15.5 Environmental Impacts

As mentioned in Section 4.1.15.4, this evaluation considered only existing manufacturing facilities, so environmental impact analyses are limited to air quality, health and safety, waste generation, and socioeconomics. Impacts are presented for the higher-temperature operating mode and a range of impacts are presented for the lower-temperature operating mode. In addition, this section contains a discussion of environmental justice.

4.1.15.5.1 *Air Quality*

The analysis used the baseline data and methods developed in DIRS 101941-USN (1996, Section 4.3) to estimate air emissions from manufacturing sites for the production of repository components. Criteria pollutants and hazardous air pollutants were considered, and predicted emissions were compared with typical regional or county-wide emissions to determine potential impacts of the emissions on local air quality.

Potential emissions were evaluated for a representative manufacturing location using the ambient air quality characteristics of typical manufacturing facilities, as described in Section 4.1.15.4. The analysis assumed that the representative location used for this analysis would be in a nonattainment area for ozone and in attainment areas for carbon monoxide and particulate matter. Therefore, ozone was the only criteria pollutant analyzed. Ozone is not normally released directly to the atmosphere, but is produced in a complex reaction of precursor chemicals (volatile organic compounds and nitrous oxides) and sunlight. This section evaluates the emissions of these precursors.

The reference air emissions associated with the manufacture of repository components were developed using the emissions resulting from manufacturing similar components (DIRS 101941-USN 1996, p. 4-6) and were normalized based on the number of work hours required for the manufacturing process. The analysis prorated these reference emissions on a per-unit basis to calculate annual emissions at the reference manufacturing site, assuming emissions from similar activities would be proportional to the number of work hours in the manufacturing process. To provide reasonable estimates of emissions, the analysis assumed that the volatile organic compounds used as cleaning fluids would evaporate fully into the atmosphere as a result of the cleaning processes used in manufacturing. The estimates of emissions were based on the total number of repository components manufactured over a 10-year period for drip shields and a 24-year period for all other components.

Table 4-46 lists the estimated annual average and estimated total emissions from the manufacture of components at the representative facility for each packaging scenario. Estimated annual average emissions of volatile organic compounds would vary from 1.0 to 1.5 metric tons (approximately 1.1 to 1.5 tons) a year for the 24-year period and from 0.59 to 0.89 metric ton (approximately 0.60 to 0.91 ton) for the 10-year drip shield manufacturing period. Nitrous oxide emissions vary from 1.3 to 1.9 metric tons (approximately 1.4 to 1.8 tons) a year for the 24-year period and from 0.76 to 1.2 metric tons (approximately 0.79 to 1.2 tons) for the 10-year drip shield manufacturing period. Annual average emissions from component manufacturing under any of the scenarios would be less than 0.05 percent of

Table 4-46. Ozone-related air emissions (metric tons)[a] at the representative manufacturing location.

Compound	Measure	Operating mode/packaging scenario[b]		
		UC	DPC	UC/DPC/DISP
		HT	HT	LT[c]
Volatile organic compounds				
24-year period[d]	Annual average	1.0	1.0	1.0 - 1.5
	24-year total	25	26	25 - 35
	Percent of *de minimis*[e]	11	12	11 - 16
10-year period[f]	Annual average	0.59	0.59	0.65 - 0.89
	10-year total	5.9	5.9	6.5 - 8.9
	Percent of *de minimis*	6.5	6.5	7.1 - 9.8
Nitrogen oxides				
24-year period	Annual average	1.3	1.4	1.3 - 1.9
	24-year total	32	33	32 - 46
	Percent of *de minimis*	15	15	15 - 21
10-year period	Annual average	0.76	0.76	0.85 - 1.2
	10-year total	7.6	7.6	8.5 - 12
	Percent of *de minimis*	8.4	8.4	9.3 - 13

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = *dual-purpose canister*; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
d. The 24-year manufacturing period is for all components except drip shields and begins 2 years prior to emplacement.
e. *De minimis* level for an air quality region in extreme nonattainment for ozone is 9.1 metric tons per year of volatile organic compounds or nitrogen oxides (40 CFR 51.853).
f. The 10-year manufacturing period is for drip shields only and occurs at repository closure.

regional emissions of volatile organic compounds and 0.005 percent of regional emissions of nitrous oxides. Emissions from the manufacture of repository components would contain a relatively small amount of ozone precursors compared to other sources.

The examination assumed that the emissions of volatile organic compounds and nitrous oxides were new sources; these emissions were compared with emission threshold levels (emission levels below which conformity regulations do not apply). There are different categories of ozone nonattainment areas based on the sources of ozone and amount of air pollution in the region. The different categories have different emission threshold levels (40 CFR 51.853).

For an air quality region to be in extreme nonattainment for ozone (most restrictive levels), the emission threshold level for both volatile organic compounds and nitrous oxides is 9.1 metric tons (10 tons) per year. Table 4-46 also lists the percentage of volatile organic compounds and nitrous oxides from the manufacture of repository components in relation to the emission threshold level of an extreme ozone nonattainment area. Annual air emissions from the manufacture of repository components would vary depending on the operating mode and packaging scenario, with ranges of 6.5 to 16 percent and 8.4 to 21 percent of the emission threshold levels for volatile organic compounds and nitrous oxides, respectively. In all of the packaging scenarios, component manufacturing would not be likely to fall under the conformity regulations because the predicted emissions of volatile organic compounds and nitrous oxides would be well below (less than 21 percent of) the emission threshold level of 9.1 metric tons per year. However, DOE would ensure the implementation of the appropriate conformity determination processes and written documentation for each designated manufacturing facility.

States with nonattainment areas for ozone could place requirements on many stationary pollution sources to achieve attainment in the future. This could include a variety of controls on emissions of volatile organic compounds and nitrous oxides. Various options such as additional scrubbers, afterburners, or carbon filters would be available to control emissions of these compounds to comply with limitations.

4.1.15.5.2 *Health and Safety*

The analysis used data on the metal fabrication and welding industries from the Bureau of Labor Statistics to compile baseline occupational health and safety information for industries that fabricate steel and steel objects similar to the repository components (DIRS 101941-USN 1996, p. 4-8). The expected number of injuries and fatalities were computed by multiplying the number of work years by the injury and fatality rate for each occupation.

Table 4-47 lists the expected number of injuries and illnesses and fatalities for each scenario based on the work years required to produce the number of components. Injuries and illnesses would range from 580 to 840, depending on the operating mode and packaging scenario. Fatalities would be unlikely.

Table 4-47. Occupational injuries, illness, and fatalities at the representative manufacturing location.[a]

	Operating mode/packaging scenario		
	Higher-temperature		Lower-temperature[b]
Parameter	UC	DPC	UC/DPC/DISP[c]
Injuries and illnesses	580	600	600 - 840
Fatalities	0.28	0.28	0.28 - 0.40

a. Impacts from 24 years for manufacture for all components except drip shields and 10 years for manufacture of drip shields.
b. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
c. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

The required number of repository components would not place unusual demands on existing manufacturing facilities. Thus, none of the scenarios would be likely to lead to a deterioration of worker safety and a resultant increase in accidents. In addition, nuclear-grade components are typically built to higher standards and with methods that are more proceduralized, both of which lead to improved worker safety.

4.1.15.5.3 *Socioeconomics*

The assessment of socioeconomic impacts from manufacturing activities involved three elements:

- Per-unit cost data for disposal containers, emplacement pallets, and drip shields (DIRS 150558-CRWMS M&O 2000, all) and per-unit cost of shipping casks (DIRS 104967-CRWMS M&O 1998, Table 12, pp. 17 and 18)
- Total number of components
- Economic data for the environmental setting for each facility to calculate the direct and secondary economic impacts of repository component manufacturing on the local economy (DIRS 103074-BEA 1992, all)
  - The local economy would be directly affected as manufacturing facilities purchased materials, services, and labor required for manufacturing.
  - The local economy would also experience secondary effects as industries and households supplying the industries that were directly affected adjusted their own production and spending behavior in response to increased production and income, thereby generating additional socioeconomic impacts.

Impacts were measured in terms of output (the value of goods and services produced), income (wages, salaries, and property income), and employment (number of jobs).

The socioeconomic analysis of manufacturing used state-level economic multipliers for fabricated metal products (DIRS 103074-BEA 1992, all). To perform the analysis, DOE obtained the product, income, and employment multipliers for the states where the five existing manufacturing facilities are located. (Multipliers account for the secondary effects on an area's economy in addition to providing direct effects on its economy). The multipliers were averaged to produce composite multipliers for a representative manufacturing location. The composite multipliers were used to analyze the impacts of each alternative. Table 4-48 lists the state-specific multipliers and the composite multipliers.

Table 4-48. Economic multipliers for fabricated metal products.[a]

State	Final demand multiplier ($)		Direct effect multiplier (number of jobs)
	Products	Earnings	
Massachusetts	1.8927	0.5555	2.2050
North Carolina	1.9145	0.5426	2.1544
Ohio	2.6019	0.7260	3.1064
Pennsylvania	2.5697	0.7194	2.8552
Tennessee	2.1379	0.6107	2.5314
Composite	2.2233	0.6308	2.5705

a. Source: DIRS 103158-Bureau of the Census (1992, all).

The analysis was limited to estimating the direct and secondary impacts of manufacturing activities. No assessment was made of the impacts of manufacturing activities on local jurisdictions. Such an analysis would include the estimation of impacts on county and municipal government and school district revenues and expenditures. Because the production of repository components probably would occur at existing facilities alongside existing product lines, a substantial population increase due to workers moving into the vicinity of the manufacturing sites in a given year under any scenario would be unlikely. Due to this lack of demographic impacts, meaningful change in the disposition of local government or school district revenues and expenditures would be unlikely. Because substantial population increases would not be likely, the analysis did not consider impacts on other areas of socioeconomic concern, such as housing and public services.

The analysis calculated average annual impacts for the manufacturing period of 10 years for drip shields and 24 years for all other components. The impacts of each packaging scenario were compared to the baseline at the representative location in 1995, with results expressed in millions of 2001 dollars. No attempt was made to forecast local economic growth or inflation rates for each representative location because of the non-site-specific nature of the analysis.

Table 4-49 lists the impacts of each operating mode and packaging scenario on output, income, and employment at the representative manufacturing location. The impacts include the percent of each scenario in relation to overall output, income, and employment in the economy.

Local Output

The average annual output impacts of each scenario would range from about $620 million to about $1,200 million (Table 4-48) depending on the operating mode and packaging scenario. Output generated from each scenario would increase total local output from between 1.8 percent and 2.4 percent, on average, over the 24-year manufacturing period, and from between 2.4 percent and 3.5 percent over the 10-year drip shield manufacturing period.

Table 4-49. Socioeconomic impacts for operating modes and packaging scenarios at the representative manufacturing location.

Flexible design/	Average annual output[b]		Average annual income		Average annual employment	
packaging scenario[a]	$ (millions)	Percent impact[c]	$ (millions)	Percent impact	Person-years	Percent impact
UC						
HT 24-year period[d]	620	1.8	180	1.1	800	0.21
HT 10-year period[e]	810	2.4	230	1.4	460	0.12
DPC						
HT 24-year period	630	1.8	180	1.1	820	0.21
HT 10-year period	810	2.4	230	1.4	460	0.12
UC/DPC/DISP[f]						
LT 24-year period	620 - 790	1.8 - 2.3	180 - 220	1.1 - 1.3	800 - 1,100	0.21 - 0.29
LT 10-year period	1,000 - 1,200	2.9 - 3.5	290 - 350	1.7 - 2.1	510 - 690	0.13 - 0.18

a. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
b. Annual output and income impacts are expressed as millions of 2001 dollars.
c. Percent impact refers to the percentage of the baseline data discussed in Section 4.1.15.4 for the representative site, escalated to 2001 dollars.
d. The 24-year manufacturing period is for all components except drip shields and begins two years prior to emplacement.
e. The 10-year manufacturing period is for drip shields only and occurs at repository closure.
f. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.

Local Income

The average annual income impacts of each packaging scenario would range from about $180 million to about $350 million (Table 4-48) depending on the operating mode and packaging scenario. Income generated from each scenario would increase total local income between 1.1 percent and 1.3 percent over the 24-year manufacturing period and from between 1.4 percent and 2.1 percent over the 10-year drip shield manufacturing period.

Local Employment

The average annual employment impacts of each packaging scenario would range from about 460 to about 1,100 work years (Table 4-48), depending on the operating mode and packaging scenario. Employment generated from any of the scenarios would increase total local employment about 0.22 percent, on average, over the 24-year manufacturing period and about 0.14 percent, on average, over the 10-year drip shield manufacturing period.

4.1.15.5.4 *Impacts on Material Use*

To the extent available, DOE based the calculations of the quantities of materials it would use for the manufacture of each component on engineering specifications for each hardware component. This information was provided by the manufacturers of systems either designed or under licensing review (DIRS 101941-USN 1996, Sections 3.0 and 4.1.1; DIRS 150558-CRWMS M&O 2000, all; DIRS 102030-CRWMS M&O 1999, all), or from conceptual design specifications for technologies still in the planning stages (DIRS 101837-JAI 1996, all). Data on per-unit material quantities for each component were combined with information on the number of components to be manufactured for each operating mode and packaging scenario. In addition, the analysis assessed the impact of component manufacturing for each scenario on the total U.S. production (or availability in the United States, if not produced in this country) of each relevant input material. The results of the assessment are expressed in terms of percent impacts on total U.S. domestic production of most commodities.

Table 4-50 lists estimated total quantities of materials that DOE would need for each packaging scenario along with the annual average requirement for each material. For each scenario the largest material

Table 4-50. Material use (metric tons).[a]

Material	Basic material use per operating mode/packaging scenario[b]					
	Higher-temperature				Lower-temperature	
	UC		DPC		UC/DPC/DISP[c]	
	Total	Annual	Total	Annual	Total	Annual
Aluminum	2,600	110	2,600	110	90 - 2,600	4 - 110
Chromium[d]	52,000	2,200	52,000	2,200	52,000 - 63,000	2,200 - 2,600
Copper	36	1	73	3	36 - 140	1 - 6
Depleted uranium	880	37	88	4	88-1,400	4 - 60
Lead	430	18	3,300	140	430 - 3,300	18 - 140
Molybdenum[e]	14,000	600	14,000	600	14,000 - 17,000	600 - 700
Nickel[f]	82,000	3,400	83,000	3,500	83,000 - 100,000	3,500 - 4,200
Steel[g]	150,000	6,300	150,000	6,300	150,000 - 330,000	6,300 - 14,000
Titanium	43,000	4,300	43,000	4,300	54,000 - 65,000	5,400 - 6,500

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the disposable canister packaging scenario.
d. Chromium estimated as 18 percent of stainless steel and 22 percent of nickel base alloy.
e. Molybdenum estimated as 13.5 percent of nickel base alloy.
f. Nickel estimated as 58 percent of nickel base alloy and 14 percent of stainless steel.
g. Steel estimated as 100 percent of carbon steel and 52 percent of stainless steel.

requirement by weight would be steel, ranging from about 150,000 to about 330,000 metric tons (160,000 to 360,000 tons), depending on the operating mode and packaging scenario.

Table 4-51 compares the annual U.S. production capacity to the annual requirements for the materials each scenario would use. With the exception of chromium, nickel, and titanium, consumption for each scenario would be less than 1.5 percent of the annual U.S. production.

Table 4-51. Annual amount (metric tons)[a] of material required for manufacturing, expressed as a percent of annual U.S. domestic production.

Material	Production[d,e,f]	Basic material use per flexible design operating mode/packaging scenario[b]					
		Higher-temperature				Lower-temperature	
		UC		DPC		UC/DPC/DISP[c]	
		Annual	Percent	Annual	Percent	Annual (max)[g]	Percent
Aluminum	5,000,000	110	0.002	110	0.002	110	0.002
Chromium	104,000	2,200	2.1	2,200	2.1	2,600	2.5
Copper	1,900,000	1	0.0001	3	0.0002	6	0.0003
Depleted uranium	14,700	37	0.25	4	0.03	60	0.41
Lead	430,000	18	0.004	140	0.03	140	0.03
Molybdenum	57,000	600	1.05	600	1.1	700	1.2
Nickel	14,600	3,400	23	3,500	24	4,200	29
Steel	91,500,000	6,300	0.007	6,300	0.007	14,000	0.01
Titanium	22,000	4,300	20	4,300	20	6,500	30

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the disposable canister packaging scenario.
d. Source: DIRS 103156-Bureau of the Census (1997, Table 1155, p. 700, and Table 1244, p. 756).
e. Source for depleted uranium production: DIRS 101941-USN (1996, p. 4-10).
f. Source for titanium production: DIRS 152457-Gambogi (1999, Volume 1, Table 2, p. 80.7).
g. Maximum from range for lower-temperature operating modes is reported here.

Therefore, the use of aluminum, copper, lead, molybdenum, depleted uranium or steel would not produce a noteworthy increased demand and should not have a meaningful effect on the supply of these materials.

The annual requirement for chromium as a component in stainless-steel and high-nickel alloy ranges from about 2.12 percent to about 2.5 percent of the annual U.S. production, depending on the flexible design operating mode and packaging scenario. Most chromium, which is an important constituent of many types of stainless steel, is imported into the United States and is classified as a Federal Strategic and Critical Inventory material. For comparative purposes, the maximum total requirement of about 63,000 metric tons (65,000 tons) can be evaluated as a percentage of the 1994 strategic chromium inventory of 1.04 million metric tons (1.15 million tons) (DIRS 103156-Bureau of the Census 1997, Table 1159, p. 702). The total repository program need would be about 6 percent of the strategic inventory. With the strategic inventory to support the program demand, chromium use should not cause any market or supply impacts.

Annual nickel use as a component in stainless steel and corrosion-resistant high-nickel alloys appears, relatively, the most important in comparison to U.S. production. The magnitude of the comparison is the result of low U.S. production because the United States imports most of the nickel it uses. Although the annual U.S. production of nickel is only 14,600 metric tons (16,100 tons), the annual U.S. consumption is 158,000 metric tons (174,000 tons) (DIRS 103156-Bureau of the Census 1997, Table 1155, p. 700). This annual consumption is supported by a robust world production of 1.04 million metric tons (1.15 million tons) (DIRS 103156-Bureau of the Census 1997, Table 1158, p. 702). The maximum annual program need is a little less than 3 percent of the U.S. consumption and about 0.5 percent of world production. Canada is a major world supplier of nickel. DOE does not anticipate that the maximum program demand would affect the U.S. or world nickel markets.

The annual amount of depleted uranium used over 24 years would range from 0.25 percent to 0.41 percent of the total U.S. annual production. These requirements would be small. Given the limited alternative uses of this material and the large current inventory of surplus depleted uranium hexafluoride owned by DOE, such impacts should be considered to be positive (DIRS 101941-USN 1996, p. 4-10). Lead or steel could be substituted for depleted uranium for radiation shielding in some cases. If those materials were used for this purpose, the thickness of the substituted material would increase in inverse proportion to the ratio of the density of the substituted material to the density of depleted uranium. If lead or steel were used, the shielding thickness would increase by about 170 percent or 240 percent, respectively, resulting in a much larger container (DIRS 101941-USN 1996, p. 4-10).

The annual requirement for titanium for drip shields ranges from about 4,300 to 6,500 metric tons (4,740 to 7,165 tons), depending on the operating mode and packaging scenario. The magnitude of the comparison is the result of low U.S. production of the basic raw material, because the United States imports most of the titanium raw material. Although the annual U.S. production of titanium raw material is only 21,600 metric tons (23,810 tons), the annual U.S. capacity to produce titanium ingots is 78,200 metric tons (86,200 tons) (DIRS 152457-Gambogi 1999, p. 80.7). The maximum annual program need is a little over 8 percent of the current annual U.S. ingot production. Titanium is classified as a Federal Strategic and Critical Inventory material and is the ninth most common element in the Earth's crust (DIRS 107031-U.S. Bureau of Mines 1985, p. 859). Because the drip shields would not be needed until repository closure, there would be adequate time (over 100 years) to complete production of titanium raw material or to import additional raw material in advance of the need to reduce impact on markets.

4.1.15.5.5 *Impacts of Waste Generation*

The component materials used in the manufacture of repository components would be carbon steel, high-nickel alloy, stainless steel, aluminum, copper, and titanium with either depleted uranium or lead used for shielding. The manufacture of shielding would generate hazardous or low-level radioactive waste, depending on the material used. Other organic and inorganic chemical wastes generated by the manufacture of repository components and the amounts generated have also been identified.

Based on data in DIRS 101941-USN (1996, p. 4-13), the analysis estimated annual volumes and quantities of waste produced for each scenario per component manufactured at the representative site. The potential for impacts was evaluated in terms of existing and projected waste handling and disposal procedures and regulations. In addition to relevant state regulatory agencies, the Environmental Protection Agency and the Occupational Safety and Health Administration regulate the manufacturing facilities.

Manufacturing to support the different flexible design operating modes and packaging scenarios would produce liquid and solid wastes at the manufacturing locations. To control the volume and toxicity of these wastes, manufacturers would comply with existing regulations. Pollution prevention and reduction practices would be implemented. The analysis evaluated only waste created as a result of the manufacturing process to produce repository components from component materials. It did not consider the waste produced in mining, refining, and processing raw materials into component materials for distribution to the manufacturer. The analysis assumed that the component materials, or equivalent component materials produced from the same raw materials, would be available from supplier stock, which would be available without regard to the status of the Yucca Mountain project.

Liquid Waste

The liquid waste produced during manufacturing would consist of used lubricating and cutting oils from machining operations and the cooling of cutting equipment. This material is currently recycled for reuse. Ultrasonic weld testing would generate some unpotable water-containing glycerin. Water used for cooling and washing operations would be treated for release by filtration and *ion* exchange, which would remove contaminants and permit discharge of the treated water to the sanitary system.

Table 4-52 lists the estimated amounts of liquid waste generated by the shaping, machining, and welding of the components required for each scenario. The annual average amount of liquid waste generated would range from 4.1 to 6.4 metric tons (approximately 4.2 to 6.5 tons) per year during either the 24-year or 10-year manufacturing periods. The small quantities of waste produced during manufacturing would not exceed the capacities of the existing equipment for waste stream treatment at the manufacturing facility.

Table 4-52. Annual average waste generated (metric tons)[a] at the representative manufacturing location.

		Operating mode/packaging scenario[b]		
		Higher-temperature		Lower-temperature
Compound	Measure	UC	DPC	UC/DPC/DISP[c]
Liquid				
24-year period[d]	Annual average	4.3	4.3	4.3 - 6.4
10-year period[e]	Annual average	4.1	4.1	4.4 - 6.2
Solid				
24-year period[d]	Annual average	0.59	0.59	0.59 - 0.88
10-year period[e]	Annual average	0.57	0.57	0.61 - 0.86

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
d. The 24-year manufacturing period is for all components except drip shields and begins two years prior to emplacement.
e. The 10-year manufacturing period is for drip shields only and occurs at repository closure.

Solid Waste

Table 4-52 lists the solid waste that manufacturing operations would generate. The annual average amount of solid waste would range from 0.57 to 0.88 metric ton (approximately 0.58 to 0.90 ton) per year during either the 24-year or the 10-year manufacturing periods. The primary waste constituents would be steel and components of steel including nickel, manganese, molybdenum, chromium, and copper. These chemicals could be added to existing steel product manufacturing waste streams for treatment and disposal or recycling.

The analysis assumed that depleted uranium to be incorporated in the components would be delivered to the manufacturing facility properly shaped to fit as shielding for a shipping cask. As a result, depleted uranium waste would not be generated or recycled at the representative manufacturing site and would not pose a threat to worker health and safety. Lead used for gamma shielding would be cast between stainless-steel components for the shipping casks. Although the production of a substantial quantity of lead waste under any of the packaging scenarios would be unlikely, such waste would be recycled.

4.1.15.5.6 *Environmental Justice*

The purpose of this environmental justice assessment is to determine if disproportionately high and adverse health or environmental impacts associated with the manufacture of repository components would affect minority or low-income populations, as outlined in Executive Order 12898 and the President's accompanying cover memorandum. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address disproportionately high and adverse human health or environmental effects of their programs and activities on minority and low-income populations. A disproportionately high impact would be an impact (or risk of an impact) in a minority or low-income community that exceeded the corresponding impact on the larger community to a meaningful degree. The analysis discussed below is the analysis used in DIRS 101941-USN (1996, Section 4.8), which was adapted to the manufacturing of components for the Yucca Mountain Repository.

The environmental justice assessment considered human health and environmental impacts from the examination of impacts on air quality, waste generation, and health and safety. The assessment used demographic data to provide information on the degree to which minority or low-income populations would be disproportionately affected. The evaluation identified as areas of concern those in which minority or low-income populations could suffer disproportionately high and adverse impacts.

This evaluation used a representative site based on five facilities that manufacture casks or canisters and related hardware for spent nuclear fuel.

To explore potential environmental justice concerns, this assessment examined the composition of populations living within approximately 16 kilometers (10 miles) of the five manufacturing facilities to identify the number of minority and low-income individuals in each area. The percentages of minority and low-income persons comprising the population of the states where the facilities are located were used as a reference. DOE selected this radius because it would capture the most broadly dispersed environmental consequences associated with the manufacturing activities, which would be impacts to air quality. The number of persons in each target group in the defined area was compared to the total population in the area to yield the proportion of minority and low-income persons within approximately 16 kilometers of each facility.

A geographic information system was used to define areas within approximately 16 kilometers (10 miles) of each facility. Linked to 1990 census data, this analytical tool enabled the identification of block groups within 16 kilometers. In cases where the 16-kilometer limit divided block groups, the system calculated the fraction of the total area of each group that was inside the prescribed distance. This fraction provided the basis for estimating the total population in the area as well as the minority and low-income components.

The analysis indicated that in one location the proportion of the minority population in the area associated with the manufacturing facility is higher than the proportion of the minority population in the state. The difference between the percentage of the minority population living inside the 16-kilometer (10-mile) radius and the state is 1.5 percent (DIRS 101941-USN 1996, p. 4-18). DOE anticipates very small impacts for the total population from manufacturing activities associated with all the scenarios, so there would be no disproportionately high and adverse impacts to the minority population near this facility.

In addition, the percentage of the total population that consists of low-income families living within about 16 kilometers (10 miles) of a manufacturing facility would exceed that of the associated state in one instance. The difference in this case was 0.9 percent (DIRS 101941-USN 1996, p. 4-18). DOE anticipates very small impacts to individuals and to the total population, and no special circumstances would cause disproportionately high and adverse impacts to the low-income population living near the facility.

The EIS analysis determined that only small human health and environmental impacts would occur from the manufacture of repository components. Disproportionately high and adverse impacts to minority or low-income populations similarly would be unlikely from these activities.

4.2 Short-Term Environmental Impacts from the Implementation of a Retrieval Contingency or Receipt Prior to the Start of Emplacement

4.2.1 IMPACTS FROM RETRIEVAL CONTINGENCY

Section 122 of the Nuclear Waste Policy Act requires DOE to maintain the ability to retrieve emplaced waste for an appropriate period after the start of emplacement. Nuclear Regulatory Commission regulations at 10 CFR 63.111(e) specify a retrieval period of at least 50 years. Because of this requirement, the EIS analyzed the impacts of retrieval. Although DOE does not anticipate retrieval and it is not part of the Proposed Action, DOE would maintain the ability to retrieve the waste for at least 100 years and possibly for as long as 324 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel. Some of the impacts that could occur during retrieval have been addressed in the Proposed Action under the lower-temperature operating mode with surface aging. This operating mode would include surface aging of up to two-thirds of the commercial spent nuclear fuel over a 50-year operations period (Chapter 2, Section 2.1.1.2.2). This aging facility could be used to store a portion of any spent nuclear fuel or high-level radioactive waste that would be retrieved.

This EIS evaluates retrieval as a contingency action and describes potential impacts if it were to occur. The analysis in this EIS assumes that under this contingency DOE would retrieve all the waste and would place it on a surface storage pad pending future decisions about its ultimate disposition. Storage of spent nuclear fuel and high-level radioactive waste on the surface would be in compliance with applicable regulations.

4.2.1.1 Retrieval Activities

If there was a decision to retrieve spent nuclear fuel and high-level radioactive waste from the repository, DOE would move the waste packages from the emplacement drifts to the surface. Operations in the subsurface facilities to remove the waste packages would be the reverse of emplacement operations and would use the same types of equipment (see Chapter 2, Section 2.1.2.2).

On the surface, the retrieved waste packages would be loaded on a vehicle for transport to a Waste Retrieval and Storage Area in Midway Valley, about 3.7 kilometers (2.3 miles) from the North Portal Operations Area, to which DOE would build a rail line or roadway. Figure 4-5 shows the relationship between these areas. The Waste Retrieval and Storage Area would include a Waste Retrieval Transfer Building, support facilities, and a number of concrete storage pads. To retrieve and store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste, these facilities would cover about 1.5 square kilometers (380 acres) (DIRS 152010-CRWMS M&O 2000, Table I-2).

DOE based its selection of Midway Valley Wash as the site for retrieval activities on the following site selection criteria:

- Proximity to the repository North Portal Operations Area
- Retrieval of the waste in the shortest possible timeframe
- Adequate space for dry storage of 70,000 MTHM of waste
- No ground displacements due to earthquakes
- Siting outside the probable maximum flood zone
- Minimum costs for construction
- Minimum impacts to the environment

In the Waste Retrieval Transfer Building, the waste packages would be removed and placed in concrete storage modules (one container per module). The concrete module would protect the container and provide shielding. The module and container would then move to a concrete storage pad near the Waste Retrieval Transfer Building, where it would remain awaiting ultimate disposition. Figure 4-6 shows a concrete storage module design concept.

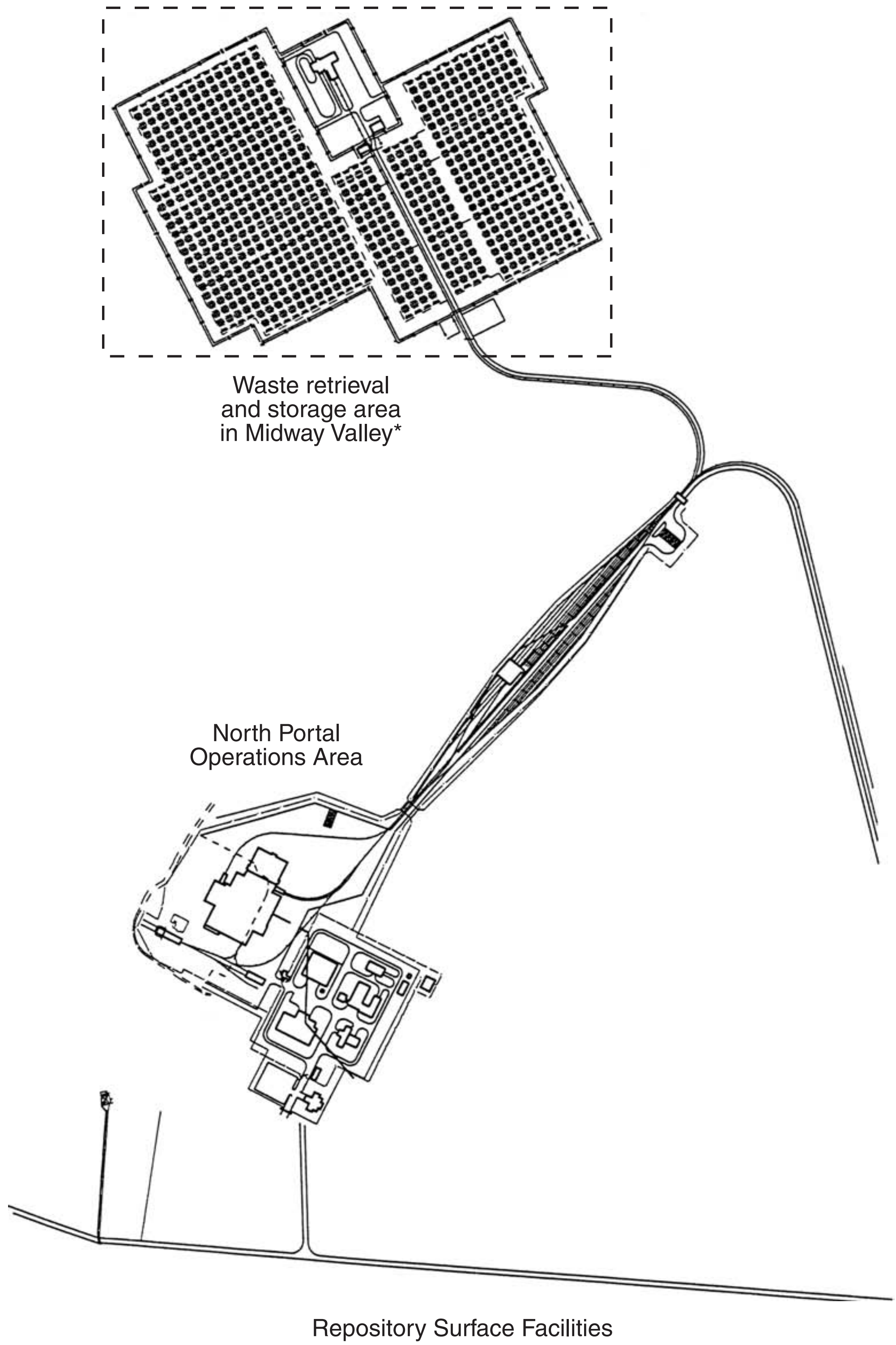
Studies of the strategies and options for retrieval (DIRS 100247-CRWMS M&O 1997, all) indicate that after a decision to retrieve the emplaced material, it would take about 10 years to plan the operation, procure the necessary equipment, and prepare the Waste Retrieval and Storage Area; subsequently, about 3 years would be needed for the initial construction of facilities and storage areas. After initial construction, the retrieval operations would require another 11 years, concurrent with an additional 7 years of storage area construction. DOE performed an impact analysis for the retrieval contingency only for the higher-temperature repository operating mode. Since 70,000 MTHM of spent nuclear fuel and high-level radioactive waste would be emplaced under the Proposed Action for all operating modes, the analysis of impacts for this operating mode is sufficient to describe the types and magnitudes of impacts that would occur if DOE implemented the retrieval contingency. Retrieval could be accomplished more quickly than the initial emplacement because limitations in material shipping and delivery as well as emplacement preparation (for example, waste package welding) would not be encountered.

4.2.1.2 Impacts of Retrieval

The following sections present the results of the environmental impact analysis for the retrieval contingency. They consider the construction of the Waste Retrieval and Storage Area, retrieval of the waste packages and their movement to the surface and to the Waste Retrieval and Storage Area, and the loading of the waste packages in concrete storage modules and their placement on concrete storage pads.

4.2.1.2.1 *Impacts to Land Use and Ownership from Retrieval*

Retrieval would cause no land use and ownership impacts during the construction of the Waste Retrieval and Storage area because the retrieval area would be on lands already withdrawn and under DOE control. DOE would develop the Waste Retrieval and Storage area on a 1.5-square-kilometer (380-acre) area approximately 3.7 kilometers (2.3 miles) north of the North Portal Operations Area in Midway Valley (see Figure 4-5). If DOE used surface aging under the lower-temperature repository operating mode, the



*See Figure 3-12 for more specific location of Midway Valley.

Source: DIRS 104508-CRWMS M&O (1999, Attachment I, Figure I-1).

Figure 4-5. Location of the Waste Retrieval and Storage Area in relation to the North Portal Operations Area.

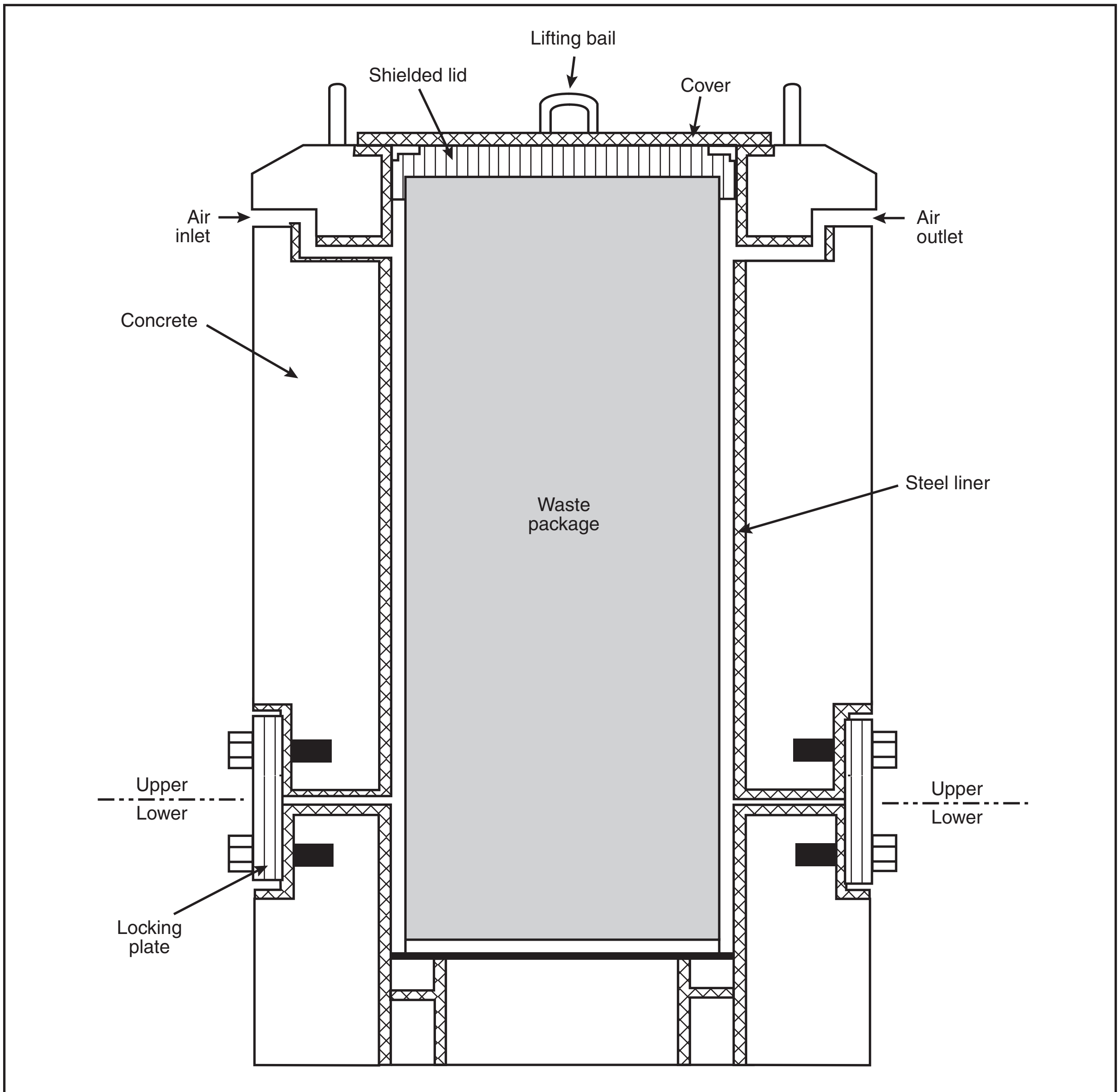


Figure 4-6. Typical concrete storage module design, vertical view.

aging pads could be available for use during retrieval operations, reducing the additional area disturbed for retrieval.

4.2.1.2.2 *Impacts to Air Quality from Retrieval*

The construction of the Waste Retrieval and Storage Area and the movement of the spent nuclear fuel and high-level radioactive waste to the surface would result in air quality impacts. The analysis considered both radiological and nonradiological impacts. No radiological air quality impacts would occur during the placement of the storage containers in concrete storage modules, assuming the containers remained intact and free from leaks during handling. However, radon-222 would be released from the active ventilation of the subsurface.

Nonradiological Air Quality Impacts. DOE evaluated nonradiological air quality impacts from the retrieval of materials from the repository for (1) the construction of a Waste Retrieval and Storage Area and (2) the retrieval process. Construction and retrieval activities would result in releases of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10}. Retrieval activities would not involve subsurface excavation or result in disturbance of the excavated rock pile, so no releases of cristobalite would occur.

Construction equipment would release nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} from fuel consumption. Fugitive dust, assumed to be all PM_{10}, would also be released during construction from earthmoving activities and operation of a concrete batch plant in the North Portal Operations Area. The analysis did not take credit for the standard construction dust suppression measures that DOE would implement to lower the projected PM_{10} concentrations. Table 4-53 lists calculated concentrations for criteria pollutant impacts at the location of the public maximally exposed individual and compares these concentrations to regulatory limits. The nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} concentrations at the location of the maximally exposed individual would be less than 2 percent of the applicable regulatory limits in all cases.

Table 4-53. Criteria pollutant impacts to public maximally exposed individual from retrieval (micro-grams per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Nitrogen dioxide	Annual	100	0.023	0.023
Sulfur dioxide	Annual	80	0.0022	0.0028
	24-hour	365	0.018	0.0049
	3-hour	1,300	0.14	0.011
Carbon monoxide	8-hour	10,000	0.20	0.0020
	1-hour	40,000	1.3	0.0033
Particulates (PM_{10}) ($PM_{2.5}$)	Annual	50 (15)	0.23	0.45
	24-hour	150 (65)	2.8	1.9

a. Appendix G, Section G.1, contains detailed information on the radiological air quality analysis.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
d. Sum of the highest concentrations at the accessible site boundary regardless of direction.

Radiological Air Quality Impacts. During retrieval activities subsurface ventilation would continue, resulting in releases of naturally occurring radon-222 and its decay products in the ventilation exhaust. Subsurface ventilation would continue for the duration of retrieval, lasting about 14 years with 3 years of initial construction (10 total years of construction), followed by 11 years of retrieval operations. Table 4-54 lists estimated annual and total doses from 14 years of retrieval activities to maximally exposed individuals and potentially affected populations from radon-222 released from subsurface facilities.

4.2.1.2.3 *Impacts to Hydrological Resources from Retrieval*

4.2.1.2.3.1 Surface Water. The retrieval activity that could have surface-water impacts would be the construction of the Waste Retrieval and Storage Area, which would disturb an area of 1.5 square kilometers (380 acres) (DIRS 152010-CRWMS M&O 2000, Table I-2).

Potential for Runoff Rate Changes. The total disturbed area would include areas cleared to support construction equipment and materials, facilities, and concrete storage pads. If DOE retrieved all the waste, the storage pad area would account for about 0.48 square kilometer (120 acres) of the disturbed land (DIRS 152010-CRWMS M&O 2000, Table I-1, p. I-12). Including the areas covered by facilities, roadways, and queuing areas, about half of the land disturbance would result in surface areas that would provide almost no infiltration, so precipitation would result in runoff from the Waste Retrieval and

Table 4-54. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during the retrieval period.[a,b]

Impact	Total	Annual
Dose to public		
Maximally exposed individual[c] (millirem)	2.7	0.19
80-kilometer[d] population[e] (person-rem)	50	3.6
Dose to noninvolved (surface) workers		
Maximally exposed noninvolved (surface) worker[f] (millirem)	0.019	0.0040
Yucca Mountain noninvolved worker population (person-rem)	0.0045	0.00039
Nevada Test Site noninvolved worker population[g] (person-rem)	0.0031	0.00033

a. Appendix G, Section G.2, contains detailed information about the radiological air quality analysis.
b. Construction and retrieval activities would last 14 years.
c. At the southern boundary of the land withdrawal area.
d. 80 kilometers = 50 miles.
e. Approximately 76,000 individuals within 80 kilometers of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker would be at the South Portal Development Area.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Storage Area. As described in Section 4.1.3.2, if precipitation did not generate runoff from surrounding areas, the runoff from the storage area could travel to otherwise empty drainage channels, but would not go far. If precipitation generated runoff everywhere, there would be little difference in the quantity produced in the storage area; it just would occur earlier in the storm. In addition, a comparison of the 1.5 square kilometers (380 acres) of disturbed land to the estimated 12 square kilometers (3,000 acres) that make up the Midway Valley Wash drainage area (DIRS 108883-Bullard 1992, Table 5) indicates that changes in runoff and infiltration rates should have little impact on how the entire drainage area responded to precipitation events.

Potential for Altering Natural Drainage. The proposed location for the Waste Retrieval and Storage Area does not cross or intercept well-defined drainage channels with the exception of the northwest corner, which could be close to, or possibly overlay, a short stretch of the upper Midway Valley Wash. Other portions of the facility would be in an area where simple overland flow probably would dominate runoff events. Design layouts of the proposed facility call for the construction of an interceptor trench along the upstream (north) side of the area, extending down either side; this would prevent runoff from entering the storage facility and could be an alteration to existing drainage. If flow in this short stretch of the upper Midway Valley Wash was intercepted, it would be diverted around the facility and then back to the existing course. Siting criteria for this proposed facility state that it will be located in a manner to minimize the engineering needed to protect it against the probable maximum flood zone (DIRS 152010-CRWMS M&O 2000, p. I-5). Therefore, a probable maximum flood in this small wash would not affect the retrieved material.

Potential for Flooding. The Waste Retrieval and Storage Area would be outside the probable maximum flood zone, although natural drainage might be altered to ensure this is the case. The interceptor trench on the north side of the facility would accommodate the highest quantities of runoff that could reasonably be present. Therefore, there would be no reasonable potential for flooding to affect the storage facility.

4.2.1.2.3.2 Groundwater. The retrieval activities that could have impacts on groundwater would be the construction of the Waste Retrieval and Storage Area and the retrieval of the emplaced material.

Potential for Infiltration Rate Changes. About half of the disturbed land would be covered by facilities, roadways, queuing areas, and storage pads. These facilities would be relatively impermeable to water, and would cause an additional amount of runoff to drainage channels in comparison to natural conditions. This additional runoff could cause a net increase in the amount of water to infiltrate these natural channels. The additional infiltration would move into the unsaturated zone and represent potential recharge to the aquifer, but it would be a minor amount in comparison to natural infiltration.

Impacts to Groundwater Resources. The estimated annual groundwater demand during retrieval would peak at about 170,000 cubic meters (140 acre-feet) a year (DIRS 152010-CRWMS M&O 2000, pp. I-18 and I-20; DIRS 150941-CRWMS M&O 2000, p. 6-20). No adverse impacts would be likely from this demand, which would be well within historic use rates.

4.2.1.2.4 *Impacts to Biological Resources and Soils*

The retrieval activity that could affect biological resources and soils would be the construction of the Waste Retrieval and Storage Area.

4.2.1.2.4.1 Impacts to Biological Resources from Retrieval. Impacts to biological resources would be similar to those described for construction and operations (see Section 4.1.4).

Impacts to Vegetation. The construction of retrieval facilities would disturb vegetation in an area that is presently undisturbed. The predominant land cover types in Midway Valley are blackbrush and Mojave mixed scrub, both of which are extensively distributed regionally and in the State of Nevada.

Impacts to Wildlife. Impacts to wildlife from the retrieval contingency would be similar to those described for the construction and operation of the repository. They would consist of limited habitat loss and the deaths of individuals of some species as a result of construction activities and vehicle traffic, and would be in addition to those associated with repository construction and operation.

Impacts to Special Status Species. Impacts to special status species from the retrieval contingency would be similar, and in addition to, those described for repository construction. They would consist of loss of a small portion of locally available habitat for the desert tortoise and the deaths of individual tortoises due to construction activities and vehicle traffic.

Impacts to Wetlands. No wetlands would be affected by activities associated with retrieval.

4.2.1.2.4.2 Impacts to Soils from Retrieval. Concrete pads, facilities, and roadways at the Waste Retrieval and Storage Area would eventually cover about half of the 1.5 square kilometers (380 acres) of disturbed land, but a sizable portion would remain as disturbed soil.

Soil Loss. Erosion concerns during the construction of the retrieval facilities would be the same as those described for the construction of the repository facilities (see Section 4.1.4.4). The types of soils encountered would be similar to, if not the same as, those encountered during the construction at the North Portal Operations Area and South Portal Development Area. As during other project activities, DOE would use dust suppression measures to reduce the disturbed land's erodibility.

After the construction of the retrieval facilities, much of the area would no longer be exposed to erosion forces because structures would cover the soil. However, the uncovered disturbed areas would be more susceptible to erosion than the surrounding natural areas. This would be the case until the disturbed land had time to reach equilibrium, including the reestablishment of vegetation. Erosion, if it occurred, probably would involve small amounts of soil from small areas. The amount of soil that could move downwind or downgradient should not present unusual concerns.

Recovery. DOE would reclaim disturbed lands when they were no longer needed for retrieval operations.

4.2.1.2.5 *Impacts to Cultural Resources from Retrieval*

The activity that could affect cultural resources would be the construction of the Waste Retrieval and Storage Area. The following sections discuss archaeological and historic resources and Native American interests in relation to retrieval.

Archaeological and Historic Resources. The results of earlier archaeological fieldwork indicate that there are no National Register-eligible archaeological resources on land recommended for the Waste Retrieval and Storage Area or near the proposed rail or road construction. Therefore, construction activities associated with retrieval probably would not result in direct impacts to National Register-eligible archaeological resources. As during repository construction and operation, increased activities and numbers of workers could increase the potential for indirect impacts to archaeological sites near the construction work.

Native American Interests. A Waste Retrieval and Storage Area in Midway Valley would be 500 meters (1,600 feet) west of the Yucca Wash local use area and Alice Hill. As described in DIRS 102043-AIWS (1998, all), these areas have cultural importance to Native Americans. There could be some direct or indirect impacts to these areas, depending on the specific locations of Native American significance boundaries.

4.2.1.2.6 *Impacts to Socioeconomics from Retrieval*

Waste retrieval activities would increase the repository workforce above that for ongoing monitoring and maintenance activities. A maximum annual employment of about 600 workers (DIRS 152010-CRWMS M&O 2000, pp. I-18 and I-20; DIRS 150941-CRWMS M&O 2000, p. 6-20) would be required during retrieval operations and concurrent storage pad construction. Retrieval would last about 14 years. Employment during retrieval would be less than during other project phases and would be unlikely to generate meaningful changes to the region of influence's employment or economic measures. Regional impacts from retrieval would be small.

4.2.1.2.7 *Occupational and Public Health and Safety Impacts from Retrieval*

The analysis of health and safety impacts to workers considered industrial safety hazards and radiological impacts from construction and retrieval operations, as discussed earlier in this section. During construction activities DOE would build (1) the surface facilities necessary to handle retrieved waste packages and enclose them in concrete storage units in preparation for their placement on concrete storage pads, and (2) the concrete storage pads (see Section 4.2.1.1). No radioactive materials would be involved in the construction activities, so health and safety impacts would be limited to those associated with industrial hazards in the workplace. DOE expects initial construction to last about 3 years, with construction of the concrete storage pads continuing concurrently with retrieval operations for an additional 7 years.

During retrieval operations DOE would retrieve the waste packages and move them to the Waste Retrieval Transfer Building. Surface facility workers would unload the waste package from the transfer vehicle and place it on a concrete base. The waste package would be enclosed in a concrete storage unit that, with the waste package inside, would be placed on the concrete storage pad. Retrieval operations would last about 11 years. The analysis estimated the health and safety impacts from both industrial hazards and from radiological hazards from operations for both surface and subsurface workers.

Radiological impacts to the public could occur during all 14 years of the retrieval period when radon-222 and its decay products would be released to the environment in the exhaust stream from the subsurface ventilation system. There would be no other source of radiation exposure to the public, and no differentiation between the construction and operations activities.

The methods used to estimate health and safety impacts to workers and the public were the same as those used to estimate such impacts for the Proposed Action (see Appendix F, Section F.2.1). Additional information pertinent to health and safety impact analysis for retrieval is contained in Appendix F, Section F.4.

Industrial Health and Safety Impacts

Industrial health and safety impacts occur only to workers. As noted above, the only health and safety impacts during retrieval construction activities would be those from industrial hazards during normal workplace activities. These impacts are shown in Table 4-55. Projected fatality would be about 0.05 and projected lost workday cases would be about 46.

Table 4-55. Health and safety impacts from industrial hazards from retrieval construction, operations, and overall impacts.[a,b]

Worker group and impact category	Construction[c]	Retrieval operations[d]	Overall impact[e]
Involved workers			
Total recordable cases	80	35	120
Lost workday cases	38	15	53
Fatalities	0.04	0.03	0.07
Noninvolved workers			
Total recordable cases	16	35	51
Lost workday cases	8	17	25
Fatalities	0.01	0.04	0.04
All workers (totals)[e]			
Total recordable cases	96	70	170
Lost workday cases	46	32	78
Fatalities	0.05	0.07	0.12

a. Numbers rounded to two significant figures.
b. Sources: Calculated using impact rates from Appendix F, Table F-71 and full-time equivalent work years from Table F-70.
c. Source: Appendix F, Table F-73.
d. Source: Appendix F, Tables F-74 and F-75.
e. Totals might differ from sums of values due to rounding.

Industrial health and safety impacts from retrieval operations are also shown in Table 4-55, as are the overall impacts. Total impacts would be small, with an estimated total of 0.12 fatality and 78 lost workday cases.

Radiological Health Impacts

Radiological health impacts may occur to both workers and members of the public. Table 4-56 lists radiological health impacts for both surface and subsurface workers for the retrieval contingency as well as the total radiological impact to all workers. Most of the radiation dose would be to subsurface workers during retrieval operations, and Appendix F contains additional details on estimates of radiation dose to subsurface workers. Impacts would be small, with the latent cancer fatality likelihood for the maximally exposed individual being about 0.002. The calculated latent cancer fatality incidence to workers for retrieval would be 0.06.

The only source of radiation exposure to members of the public during construction and retrieval operations would be from releases of radon-222 and its decay products through the subsurface ventilation system exhaust. Table 4-54 presents the estimated radiation doses to members of the public from these releases.

Table 4-56. Radiological health impacts to workers from retrieval operations.[a,b,c]

Worker group and impact category	Surface facility workers	Subsurface facility workers	High/total[d]
Maximally Exposed Worker dose (rem)			*High*
Involved	0.28	5.9	5.9
Noninvolved	0	0.44	0.44
Probability of latent cancer fatality			
Involved	0.00011	0.002	0.002
Noninvolved	0	0.0002	0.0002
Worker population			*Total*
Collective dose (person-rem)			
Involved	8	120	130
Noninvolved	0	4	4
Total[e]	**8**	**130**	**140**
Number of latent cancer fatalities			
Involved	0.003	0.05	0.05
Noninvolved	0	0.002	0.002
Total[e]	**0.003**	**0.05**	**0.06**

a. Sources: Appendix F, Tables F-76 and F-77.
b. All impacts from operations. Radiological health impacts to workers during construction would be minimal.
c. Numbers are rounded to two significant figures.
d. Highest individual and population totals for the 11-year retrieval period.
e. Totals might differ from sums of values due to rounding.

Table 4-57 lists estimated radiological health impacts to the public for retrieval. The estimated radiological health impacts to members of the public from the retrieval contingency would be small. The likelihood of a latent cancer fatality for the maximally exposed individual would be about 0.0000013. The estimated latent cancer fatality incidence in the exposed population would be about 0.025.

Table 4-57. Radiological health impacts to the public for the retrieval period.

Worker group and impact category	Impact
Individual	
Maximally exposed individual dose (millirem)[a]	2.7
Latent cancer fatality probability	0.0000013
Population	
Collective dose (person-rem)[a]	50
Latent cancer fatality incidence	0.025

a. Source: Table 4-54.

4.2.1.2.8 *Impacts from Accidents During Retrieval*

During retrieval operations, activities at the repository would be essentially the reverse of waste package emplacement, except operations in the Waste Handling Building would not be necessary because the waste packages would not be opened. The handling accident scenario applicable for these operations would be bounded by the transporter runaway accident scenario evaluated in Section 4.1.8. The waste packages would be retrieved remotely from the emplacement drifts, transported to the surface, and transferred to a Waste Retrieval and Storage Area (DIRS 102702-CRWMS M&O 1997, all). This area would include a Waste Retrieval Transfer Building where the waste packages would be unloaded from the transporter, transferred to a vertical concrete storage unit, and moved to a concrete storage pad.

Because the retrieval operations would be essentially the same as the emplacement operations (in reverse), the accident scenarios involving the waste package during operations would bound the retrieval operation. The bounding accident scenario during emplacement would be a transporter runaway and derailment accident in a main drift (see Appendix H, Section H.2.1.4). For above-ground storage accidents, the accident analysis for the continued storage analysis would apply. Recent analyses have found that the only credible accident with the potential for radiological consequences would be an aircraft crash into one of the above-ground storage facilities. However, the aircraft would not penetrate the thickness of the waste package (DIRS 157108-Jason 2001, all).

The analysis assumed that above-ground storage following retrieval would be licensed in compliance with Nuclear Regulatory Commission requirements (10 CFR Part 72). These requirements specify that storage modules must be able to withstand credible accident-initiating events.

4.2.1.2.9 *Noise Impacts from Retrieval*

The analysis in Section 4.1.9 shows that there would be no appreciable noise impacts for the construction, operation and monitoring, and closure phases of repository operations. Noise impacts associated with retrieval would be less than those associated with repository operations because of the reduced scope of activities and the smaller number of workers required. Thus, noise impacts from retrieval operations would be small.

4.2.1.2.10 *Aesthetic Impacts from Retrieval*

Retrieval activities would not be likely to produce adverse impacts on the visual quality of the landscape surrounding Yucca Mountain. Retrieval would essentially be the reverse of emplacement and would use the same types of equipment. Impacts from emplacement would be small. The only difference from the emplacement activities would be the construction of a Waste Retrieval and Storage Area in Midway Valley north of the North Portal Operations Area with a connecting transportation corridor. These activities would occur in the repository area and in Class C scenic quality lands away from the public view and, therefore, would have no impact on the existing visual character of the landscape.

4.2.1.2.11 *Impacts to Utilities, Energy, Materials, and Site Services from Retrieval*

The following sections discuss utility, energy, materials, and site service impacts.

Utilities and Energy. The estimated electric power demand for retrieval would be less than 10 megawatts. This demand would be well within the capacity that would be available at the repository.

The fossil-fuel use estimated for retrieval activities would approach 25 million liters (6.6 million gallons). This consumption level is less than 0.1 percent of the annual consumption in the State of Nevada. In addition, the repository would use about 2 million liters (530,000 gallons) of hydraulic oil and lubricants, which DOE would recycle.

Materials. For the Waste Retrieval and Storage Area, DOE would build a concrete pad and retrieval support facilities. Construction would require about 600,000 cubic meters (780,000 cubic yards) of concrete and 46,000 metric tons (51,000 tons) of steel, which would not affect the regional supply capacity. About 11,000 concrete storage modules would be required. The concrete would be obtained from offsite sources or the onsite batch plant would be used. The storage modules would be relatively simple concrete vessels with a 0.64-centimeter (0.25-inch) steel liner. About 121,000 cubic meters (158,000 cubic yards) of concrete would be required to build 11,000 modules, which probably would be manufactured commercially. Material usage impacts would be small. The impacts of shipping about 11,000 concrete storage modules to the site would be comparable to those for shipping about 11,000 disposal containers to the site (see Chapter 6, Section 6.1.3).

Site Services. The onsite emergency response capability and the security, medical, and fire protection units that would support operations would be available to support retrieval, so no additional impacts would be likely.

Table 4-58 summarizes impacts to utilities, energy, and materials.

Table 4-58. Utilities, energy, and materials for retrieval.[a,b,c]

Location	Electric		Fossil fuel		Construction materials	
	Peak (MW)[d,e]	Use (1,000 MWh)[f]	Liquid fuels (million liters)[g]	Oils (million liters)	Concrete (1,000 cubic meters)[h]	Steel (1,000 metric tons)[i]
Surface	1.3	83	21	0.034	600	46
Subsurface	7.7	700	0.3	2.2	0	0
Totals	***9.0***	***780***	***21.3***	***2.2***	***600***	***46***

a. Sources: DIRS 104508-CRWMS M&O (1999, pp. I-22 to I-24); DIRS 104523-CRWMS M&O (1999, p. 6-35).
b. All entries except peak electric power are cumulative totals for the entire period.
c. Approximate retrieval period would be 14 years.
d. Peak electric power is the peak demand that would occur during the period.
e. MW = megawatts.
f. MWh = megawatt-hours.
g. To convert liters to gallons, multiply by 0.26418.
h. To convert cubic meters to cubic yards, multiply by 1.3079.
i. To convert metric tons to tons, multiply by 1.1023.

4.2.1.2.12 *Impacts to Waste Management from Retrieval*

The construction of the Waste Retrieval and Storage Area would generate an estimated maximum of 13,000 cubic meters (460,000 cubic feet) of construction debris, 2,800 cubic meters (99,000 cubic feet) of sanitary and industrial solid waste, and 520 cubic meters (18,000 cubic feet) of hazardous waste (DIRS 104508-CRWMS M&O 1999, p. I-22). Based on operations generation rates, retrieval of the waste packages would generate an estimated 4,900 cubic meters (170,000 cubic feet) of sanitary and industrial solid waste. Throughout the construction of the retrieval facilities and retrieval operations, the workforce would generate sanitary sewage. After the spent nuclear fuel and high-level radioactive waste were placed in the concrete storage modules and on the concrete storage pads, waste generation would continue due to the presence of a workforce. Surveillance and monitoring activities would generate sanitary and industrial solid and low-level radioactive waste.

Construction debris and sanitary and industrial solid waste would be disposed of at onsite facilities or at the Nevada Test Site. Sanitary sewage would be disposed of at onsite facilities. Low-level radioactive waste would be disposed of at the Nevada Test Site or another government or commercial facility in accordance with applicable Federal and state requirements. Hazardous waste would be shipped off the site for treatment and disposal at a permitted commercial facility. As discussed in Section 4.1.12, the available capacity for hazardous waste treatment and disposal in the western states would exceed the demand. Assuming this trend would continue, hazardous waste possibly generated during retrieval activities would have a very small impact on the capacity for treatment and disposal at commercial facilities.

4.2.1.2.13 *Impacts to Environmental Justice from Retrieval*

Workers at the Yucca Mountain site would be representative of the population mix in the surrounding areas of Nevada. Hence, there would be no disproportionate impacts to minority or low-income workers in the Yucca Mountain region during retrieval activities. Disproportionate impacts to minority or low-income populations from retrieval construction and operation activities would be unlikely. Impacts to areas of cultural importance to American Indians could vary depending on the conduct of activities and the location of significance boundaries.

4.2.2 IMPACTS FROM RECEIPT PRIOR TO THE START OF EMPLACEMENT

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For this EIS, DOE assumed that the receipt and emplacement of spent nuclear fuel and high-level radioactive waste would begin in 2010 and occur over a 24-year period (70,000 MTHM at approximately 3,000 MTHM per year), unless surface aging was used, in which case there would be a 50-year operations period. The EIS considers the potential for the transport of spent nuclear fuel or high-level radioactive waste to the Yucca Mountain site several years before the waste was actually emplaced in the repository as a contingency action, not part of the Proposed Action. DOE recognizes that regulatory changes would have to occur for the receipt of spent nuclear fuel and high-level radioactive waste before the start of emplacement, and would have to build a facility similar to that described as part of the retrieval contingency (Section 4.2.1.1) for the receipt of these materials pending their emplacement.

Such a facility would consist of a series of concrete pads in the Midway Valley Wash area (the same area described for the retrieval contingency). The facility would be capable of storing as much as 40,000 MTHM of spent nuclear fuel and high-level radioactive waste in concrete storage modules.

The types of impacts resulting from the construction and operation of a Waste Staging Facility would be similar to those from the implementation of a retrieval contingency, described in Section 4.2.1. The impacts would include land disturbance, emission of particulate and gaseous pollutants, and radiation doses from the handling of spent nuclear fuel and high-level radioactive waste. In all cases, potential impacts would be bounded by those presented for the lower-temperature operating mode in Section 4.1.

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Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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5

Environmental Consequences of Long-Term Repository Performance

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5. ENVIRONMENTAL CONSEQUENCES OF LONG-TERM REPOSITORY PERFORMANCE

This chapter describes potential human health impacts from radioactive and nonradioactive materials released to the environment during the first 10,000 years after closure of a repository at Yucca Mountain. The impact calculations assumed that the population in the Yucca Mountain region would remain constant at the number of people projected to live in the region in 2035, as discussed in Chapter 3, Section 3.1.7.1. This chapter also estimates the peak radiation dose during the first 1 million years after closure. Closure of a repository would include the following events, which are analyzed in Chapter 4:

- Sealing of the underground emplacement drifts
- Backfilling and sealing of other underground openings
- Removal of the surface facilities
- Creation of institutional controls, including land records and surface monuments, to identify the location of the repository and discourage human intrusion

In addition, this chapter discusses estimates of potential biological impacts from radiological and chemical groundwater contamination and potential environmental impacts of such contamination and potential biological impacts from the long-term production of heat due to decay of the radioactive materials that would be disposed of in a repository at Yucca Mountain; and potential environmental justice impacts. Other than human impacts, these would be the only potential long-term impacts. There would be no repository activities; no changes in land use, employment of workers, water use or water quality other than from the transport of radionuclides; and no use of energy or other resources, or generation or handling of waste after closure of a repository. Therefore, analysis of impacts to land use, noise, socioeconomics, cultural resources, surface-water resources, aesthetics, utilities, or services after closure is not required. As part of closure activities, the U.S. Department of Energy (DOE, or the Department) would return the land to its original contour and erect appropriate monuments marking the repository, which would result in some minor impacts on aesthetics depending on the exact design of the monuments (currently undetermined). Impacts from closure are discussed in Chapter 4. After the completion of closure, risk of sabotage or intruder access would be highly unlikely. Chapter 4 (Section 4.1.8.3) discusses the potential for sabotage prior to closure. Section 5.7.1 discusses potential impacts from an intruder after closure.

DOE performed the analysis of potential impacts after repository closure for two operating modes—higher-temperature and lower-temperature. For analysis purposes, the same fundamental repository design was used in both modes, but the heat output per unit area of the repository was varied by changing waste package spacing and other operational parameters (see Section 2.1.1.2 in Chapter 2 for details).

The analysis for this EIS considered the following three transport pathways through which spent nuclear fuel, high-level radioactive waste, and hazardous or *carcinogenic* chemicals could reach human populations and cause health consequences:

- Groundwater
- Surface water
- Atmosphere

The principal *exposure pathway*, groundwater, would result from rainwater migrating down through the unsaturated zone into the repository, dissolving some of the material in the repository, and carrying contaminants from the dissolved material downward through the unsaturated zone and on through the groundwater system to locations where human exposure could occur. A surface-water pathway could occur if groundwater reached the surface at a discharge location, so the analysis for this Final EIS considered surface-water consequences along with groundwater consequences. An airborne pathway could result because spent nuclear fuel contains some radionuclides in gaseous form. For example, carbon-14 could migrate to the surface in the form of carbon dioxide gas and mix in the atmosphere.

The analysis for this EIS estimated potential human health impacts from the groundwater transport pathway at three locations in the Yucca Mountain groundwater hydrology region of influence:

- Water wells at the *reasonably maximally exposed individual* (RMEI) location [For this EIS, DOE determined that the RMEI location would be at the southern-most point of the controlled area, as specified in 40 CFR Part 197 (36 degrees, 40 minutes, 13.6661 seconds north latitude). Groundwater modeling indicates that the point at which the predominant groundwater flow crosses the boundary would be about 18 kilometers (11 miles) downgradient from the potential repository. This EIS refers to this location as the "RMEI location."]
- 30 kilometers (19 miles) downgradient from the potential repository.
- The nearest surface-water discharge point, which is about 60 kilometers (37 miles) downgradient from the potential repository.

These consequences are presented in terms of radiological dose and the probability of a resulting latent cancer fatality. A latent cancer fatality is a death resulting from cancer caused by exposure to ionizing radiation or other carcinogens.

WASTE PACKAGE

A *waste package* consists of the waste form and any containers (disposal container, barriers, and other canisters), spacing structure or baskets, shielding integral to the container, packing in the container, and other absorbent materials immediately surrounding an individual disposal container, placed inside the container, or attached to its outer surface. The waste package begins its existence when the outer lid welds are complete and accepted and the welded unit is ready for emplacement in the repository.

DOE assessed the processes by which waste could be released from a repository at Yucca Mountain and transported to the environment. The analysis used computer programs developed to assess the release and movement of radionuclides and hazardous materials in the environment. Some of the programs analyzed the behavior of engineered components such as the waste package, while others analyzed natural processes such as the movement of groundwater. The programs are based on the best available geologic, topographic, and hydrologic data and current knowledge of the behavior of the materials proposed for the system. The analysis used data from the Yucca Mountain site characterization activities, material tests, and expert opinions as input parameters to estimate human health consequences. Many parameters used in the analysis cannot be exactly measured or known; only a range of values can be known. The analysis accounted for this type of uncertainty; thus, the results are ranges of potential health consequences.

The analysis for this Final EIS considered human health impacts during the first 10,000 years after repository closure and the peak dose during the first 1 million years after repository closure. Estimates of potential human health impacts from the *nominal scenario* (undisturbed by volcanic activity or human intrusion) included the effects of such expected processes as corrosion of waste packages, dissolution of waste forms, flow through the saturated and unsaturated zone, seismic events, and changing climate. Additional analyses examined the effects of exploratory drilling, criticality, and volcanic events.

A number of changes have occurred since the issuance of the Draft EIS. Several changes have been made to the repository and waste package designs and many changes have been made to the models used to analyze long-term repository performance. Key design changes important to the long-term performance include changes to the waste package design, changes to how thermal loading of the repository is implemented, and addition of titanium drip shields over the waste packages. Chapter 2, Section 2.1.2; Chapter 4, Section 4.1; Section 5.2; and Appendix I, Section I.2, and the supporting documents referenced therein contain more details on the design changes. In addition, many improvements have been made to the analysis models. These improvements have enhanced the sensitivity of the models to more processes and effects and have refined treatment of uncertainties in some areas. Table 5-1 summarizes the changes. The changes identified in the column titled "S&ER Reference" were addressed in the Supplement to the Draft EIS. The other changes identified in Table 5-1 are addressed in this Final EIS. Further details can also be found in the references cited in Table 5-1 and in Appendix I, Section I.2. The relationship between published Total System Performance Assessment (TSPA) models and both the Draft EIS and this Final EIS are provided in Figure 5-1.

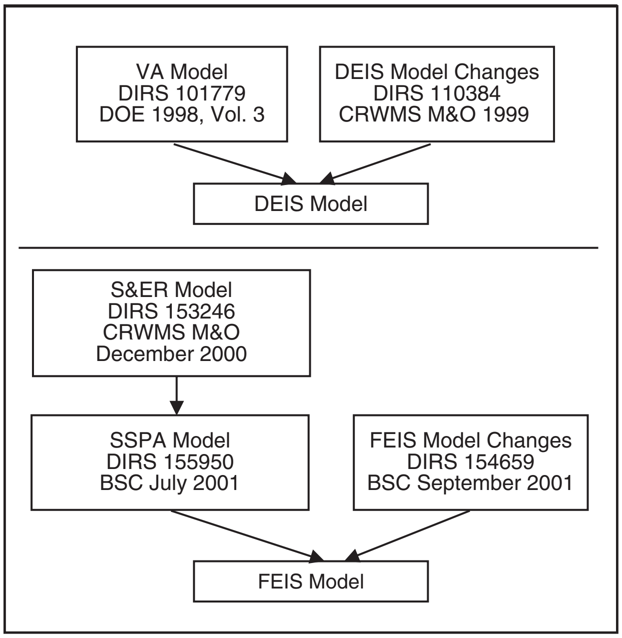

Figure 5-1. Relationship between the published TSPA models and models used for both the Draft EIS and this Final EIS.

5.1 Inventory for Performance Calculations

DOE proposes to dispose of approximately 11,000 to 17,000 waste packages containing as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain. There are several different types of disposal containers for commercial spent nuclear fuel and different container designs for DOE spent nuclear fuel and high-level radioactive waste. The exact number of waste packages would depend on various options in the proposed design. This long-term consequence analysis identified the inventory by the source category of waste material to be disposed of (commercial spent nuclear fuel, DOE spent nuclear fuel, weapons-usable plutonium, and high-level radioactive waste). For purposes of modeling, the inventory for each of the categories was averaged into an appropriate number of packages, each with identical contents. The average of the modeled inventories resulted in a total of nearly 12,000 idealized waste packages (slightly higher than the actual number of waste packages that would be emplaced) in two basic types.

Note that while the simulations were based on the nearly 12,000 packages, there would be no difference in the result if the smaller packages had been used (17,000 package case). This is because the use of smaller packages is merely a way of implementing the lower-temperature operating mode and would contain the same proposed inventory.

5.1.1 INVENTORY OF RADIOACTIVE MATERIALS

There are more than 200 radionuclides in the waste inventory (see Appendix A). The analysis for this Final EIS used a reduced number of radionuclides (26; see Appendix I, Section I.3).

Table 5-1. Changes to the TSPA model since publication of the Draft EIS (page 1 of 2).

Submodel	Change	Estimated effect	S&ER reference[a]	SSPA reference[b]	Model for this Final EIS[c]
Inventory	New inventory abstraction	Neutral	4.2.6.4.1		
	U.S. Navy spent nuclear fuel modeled as commercial spent nuclear fuel rather than as DOE-owned spent nuclear fuel	Neutral			5.2
Unsaturated zone flow	Updated climate model	Neutral	4.2.1.1.1		
	Added interaction of moisture in fractures and rock matrix	Possible reduction in dose	4.2.1.1.4		
	Added perched water models	Neutral	4.2.1.3.1.2		
	Flow through unsaturated zone and, therefore, seepage varies with time	More climate sensitivity, possible increase in dose	4.2.1.3.6		
	Flow-focusing within heterogeneous permeability field; episodic seepage	Possible increase in dose		4.3.1, 4.3.2, 4.3.5	
	Multiscale thermal-hydrologic model, including effects of rock dryout	Possible increase in dose		5.3.1	
	Thermal property sets	Neutral		5.3.1	
	Thermal effects on seepage	Possible increase in dose		4.3.5	
	Coupling between thermal, hydrologic, and chemical effects	Possible increase in dose	4.2.2.1.2		
Waste package and drip shield degradation	Changes to model new package design and addition of drip shield model	Decrease in dose up to 10,000 years	4.2.4.3		
	Improved early package failure model	Decrease in dose up to 10,000 years		7.3.2	
	Experimental corrosion data replacing expert judgment	Decrease in dose up to 10,000 years, increase in peak dose after 10,000 years	4.2.4.3.2		
	General corrosion rate independent of temperature	Increase in dose			5.2
Waste form degradation	Updated cladding degradation model to include mechanical failures and localized corrosion	Increase in dose	4.2.6.3.3		
	Add comprehensive model of colloid formation effects on radionuclide mobilization	Increase in dose	4.2.6.3.8		
	Increased number of radionuclides modeled from 9 to 21	Increase in dose	4.4.1.4		
	Neptunium solubility model incorporating secondary phases	Decrease in dose after 10,000 years	4.2.6.3.7		
Engineered barrier system transport	New comprehensive model for transport of radionuclides from colloid effects	Increase in dose	4.2.7.4.2		
Unsaturated zone transport	New comprehensive model for transport of radionuclides from colloid effects	Increase in dose	4.2.8.4.3		
	Model updated to include radiation connections in the thermal-hydrologic submodel for the lower-temperature operating mode	Neutral			5.2
	Effect of drift shadow zone-advection/ diffusion splitting	Decrease in dose		11.3.1	

Table 5-1. Changes to the TSPA model since publication of the Draft EIS (page 2 of 2).

Submodel	Change	Estimated effect	S&ER reference[a]	SSPA reference[b]	Model for this Final EIS[c]
Saturated zone flow and transport	Colloid-facilitated transport in two modes: as an irreversible attachment of radionuclides to colloids, originating from waste, and as an equilibrium attachment of radionuclides to colloids	Increase in dose	4.2.9.4		
	Three-dimensional transport model	Neutral	4.2.9.4		
	Plume capture method for well concentrations (total radionuclides dissolved in water usage)	Possible decrease in dose	4.2.9.4		
	Change in length of saturated zone from 20 kilometers (12 miles) downgradient from the potential repository for MEI[d] in Draft EIS to RMEI[e] location determined by DOE to be approximately 18 kilometers, or 11 miles, downgradient from the potential repository	Possible increase in dose			5.2
Biosphere	Change in basis for biosphere dose conversion factors from MEI in the Draft EIS to the average member of the critical group defined in draft 10 CFR Part 63	Neutral	4.2.10.1		
	Change in basis for biosphere dose conversion factors from the average member of the critical group (10 CFR Part 63) in the S&ER and SSPA to the RMEI defined in EPA regulation 40 CFR Part 197	Slight decrease			5.2
	Consideration of groundwater protection standards	New impact measure	4.4.2		
	Change in water volume used for evaluation of groundwater protection standards from sampled model dilution volume to the representative volume (3,000 acre-feet per year) defined in EPA regulation 40 CFR Part 197	Decrease in new impact measure			5.2

a. Section numbers in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (DIRS 153849-DOE 2001, all).
b. Section numbers in the SSPA-*Supplemental Science and Performance Analysis* (DIRS 155950-BSC 2001, all).
c. Section numbers in DIRS 157307-BSC (2001, Enclosure 1).
d. MEI = maximally exposed individual.
e. RMEI = reasonably maximally exposed individual.

The number of radionuclides to be analyzed was determined by a screening analysis. The screening analysis identified those radionuclides that would collectively contribute at least 95 percent of the dose to a person living in the vicinity of Yucca Mountain. The list of radionuclides resulting from the screening process forms the basis for the analyses discussed in this chapter. Appendix I, Section I.3, contains more details of this screening analysis.

The total inventory was abstracted into two types of idealized waste packages: a codisposal package with high-level radioactive waste in a glass matrix and DOE spent nuclear fuel, and a commercial spent nuclear fuel package. Table 5-2 lists the abstracted inventory for the idealized waste packages. For

IDEALIZED WASTE PACKAGES

The number of waste packages used in the performance assessment simulations do not exactly match the number of actual waste packages projected for the Proposed Action.

The TSPA model uses two types of *idealized waste packages* (commercial spent nuclear fuel package and codisposal package), representing the averaged inventory of all the actual waste packages used for a particular waste category.

While the number of idealized waste packages varies from the number of actual waste packages, the total radionuclide inventory represented by all of the idealized waste packages collectively is representative of the total inventory, for the radionuclides analyzed, given in Appendix A of this EIS for the purposes of analysis of long-term performance. The abstracted inventory is designed to be representative for purposes of analysis of long-term performance and cannot necessarily be used for any other analysis, nor can it be directly compared to any other abstracted inventory used for other analyses in this EIS.

Table 5-2. Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package.[a,b]

Nuclide	Commercial spent nuclear fuel waste packages[c]	Codisposal waste packages[d]	
		DOE spent nuclear fuel	High-level radioactive waste
Actinium-227	0.00000309	0.000113	0.000467
Americium-241	10,900	117	65.7
Americium-243	1,290	1.49	0.399
Carbon-14	1.37	0.0496	0.00643
Cesium-137	5,340	112	451
Iodine-129	1,800	25.1	48
Neptunium-237	4,740	47.9	72.3
Protactinium-231	0.00987	0.325	0.796
Lead-210	0	0.000000014	0.000000114
Plutonium-238	1,510	6.33	93.3
Plutonium-239	43,800	2,300	3,890
Plutonium-240	20,900	489	381
Plutonium-242	5,410	11.1	7.77
Radium-226	0	0.00000187	0.0000167
Radium-228	0	0.00000698	0.00000319
Strontium-90	2,240	55.4	288
Technetium-99	7,680	115	729
Thorium-229	0	0.0266	0.00408
Thorium-230	0.184	0.0106	0.00782
Thorium-232	0	14,900	7,310
Uranium-232	0.0101	0.147	0.000823
Uranium-233	0.07	214	11.1
Uranium-234	1,830	57.2	47.2
Uranium-235	62,800	8,310	1,700
Uranium-236	39,200	853	39.8
Uranium-238	7,920,000	509,000	261,000

a. Source: DIRS 154841-BSC (2001, Table 36, p. 38).
b. The idealized waste packages in the simulation (model) are based on the inventory abstraction in Appendix I, Section I.3. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the potential repository would be different.
c. There are 7,860 idealized commercial spent nuclear fuel waste packages.
d. There are 3,910 idealized codisposal waste packages.

analysis purposes, naval spent nuclear fuel is conservatively modeled as commercial spent nuclear fuel (DIRS 152059-BSC 2001, all; DIRS 153849-DOE 2001, Section 4.2.6.3.9, p. 4-257).

5.1.2 INVENTORY OF CHEMICALLY TOXIC MATERIAL

DOE is not proposing to dispose of chemically toxic waste in the potential repository. However, the degradation of engineered materials that would be used in repository construction and engineered barrier systems would result in corrosion products that contain chemically toxic materials.

A screening analysis reported in Appendix I (Section I.6.1) showed that the only chemical materials of concern for the 10,000-year analysis period were those released as the external wall of the waste package and the waste package support pallet materials corroded. The chemicals of concern would be chromium, nickel, molybdenum, and vanadium. The exposed surface areas that would corrode include Alloy-22 surfaces (drip shield rails, outer layer of waste packages, and portions of the emplacement pallets) and stainless steel 316NG surfaces (portions of the emplacement pallets).

The total quantities of materials would be 86,000,000 kilograms (190,000,000 pounds) of Alloy-22 (DIRS 150558-CRWMS M&O 2000, p. 6-6) containing 22.5 percent chromium, 14.5 percent molybdenum, 57.2 percent nickel, 0.35 percent vanadium (DIRS 104328-ASTM 1998, all) and 140,000,000 kilograms (310,000,000 pounds) of stainless steel, (DIRS 150558-CRWMS M&O 2000, p. 6-6) which is 17 percent chromium, 12 percent nickel and 2.5 percent molybdenum. A large percentage of the stainless steel would be inside the waste package (as an inner sleeve) and, therefore, much of this material would not be exposed until the Alloy-22 had corroded away.

5.2 System Overview

Radioactive materials in the repository would be placed at least 200 meters (660 feet) beneath the surface (DIRS 154554-BSC 2001, pp. 28-29). In physical form, the emplaced materials would be almost entirely in the form of solids with a very small fraction of the total radioactive inventory in the form of trapped gases (see Section 5.5). With the exception of a small amount of radioactive gas in the fuel rods, the primary means for the radioactive and chemically toxic materials to contact the *biosphere* would be along groundwater pathways. The materials could pose a threat to humans if the following sequence of events occurred:

- The waste packages and their contents were exposed to water
- Radionuclides or chemically toxic materials in the package materials or wastes became dissolved or mobilized in the water
- The radionuclides or chemically toxic materials were transported in water to an aquifer, and the water carrying radionuclides or chemically toxic materials was withdrawn from the aquifer through a well or at a surface-water discharge point and used directly by humans for drinking or in the human food chain (such as through irrigation or watering livestock).

Thus, the access to, and flow of, contaminated water are the most important considerations in determining potential health hazards.

5.2.1 COMPONENTS OF THE NATURAL SYSTEM

Figure 5-2 is a simplified schematic of a repository at Yucca Mountain. It shows the principal features of the natural system that could affect the long-term performance of the repository. Yucca Mountain is in a semiarid desert environment where the current average annual precipitation over the unsaturated zone flow and transport model area is 170 millimeters (7 inches), varying by specific location (DIRS 153849-DOE 2001, p. 4-38). The water table is an average of about 600 meters (2,000 feet) below the surface of the mountain. The proposed repository would be in unsaturated rock approximately midway between the desert environment and the water table.

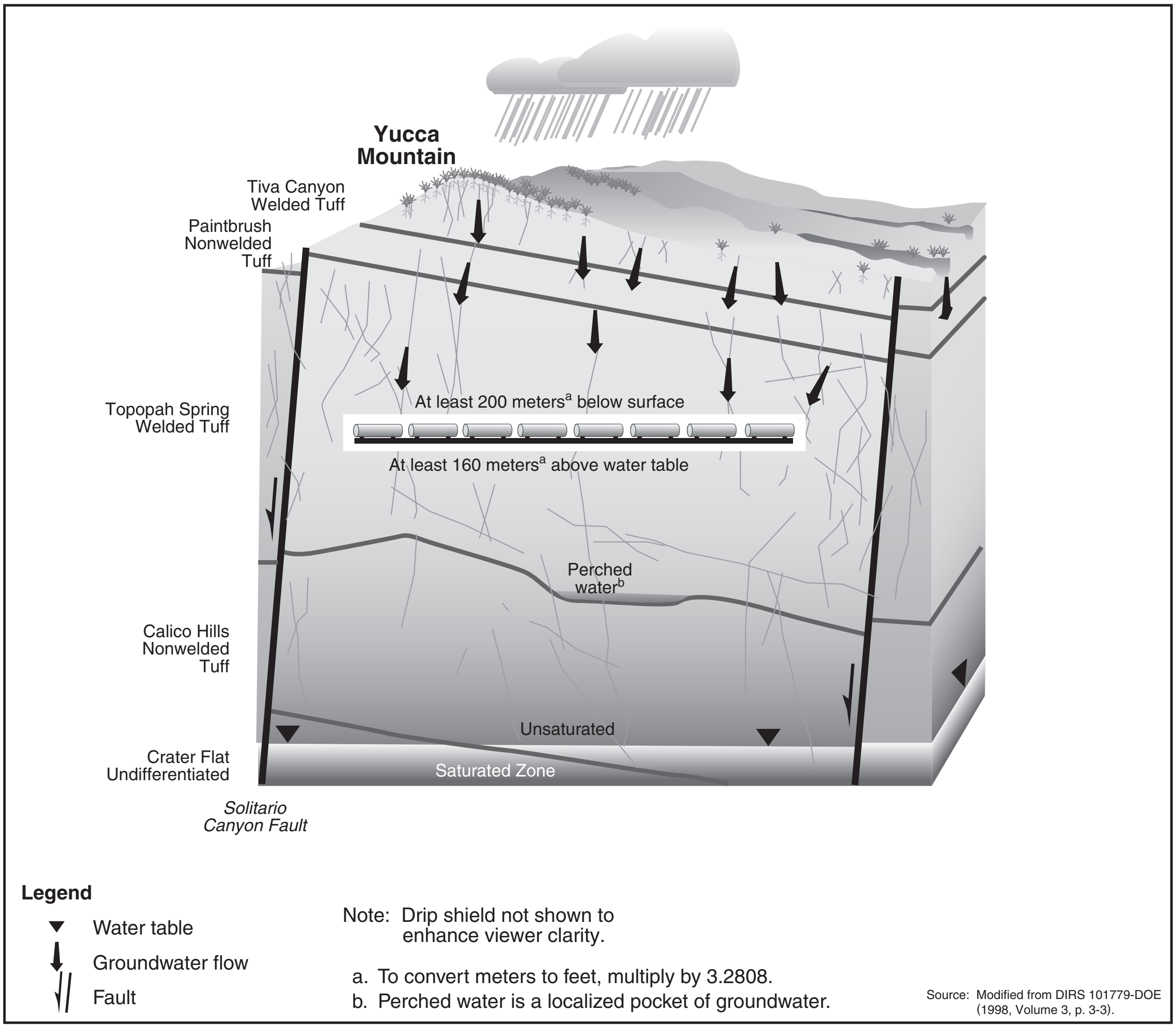

Figure 5-2. Components of the natural system.

The water table is the boundary between the unsaturated zone above and the saturated zone below. In the subsurface region above the water table, the rock contains water but the water does not fill all the open spaces in the rock. Because the open spaces are only partially filled, this region is called the unsaturated zone. Water in the unsaturated zone tends to move generally downward in response to capillary action and gravity. In contrast, water fills all the open spaces in the rock below the water table, so this region is called the saturated zone. Water in the saturated zone tends to flow laterally from higher to lower pressures. Both zones contain several different rock types, as shown in Figure 5-2. The layers of major rock types in the unsaturated zone at the Yucca Mountain site are the Tiva Canyon welded, Paintbrush nonwelded, Topopah Spring welded, Calico Hills nonwelded, and Crater Flat undifferentiated tuffs. Figure 5-2 shows two of the faults at the proposed site-the Ghost Dance fault that occurs within the repository block and the Solitario Canyon Fault that forms the western boundary of the repository block. Faults are slip zones where rock units have become displaced either vertically, laterally, or diagonally, resulting in the rock layers being discontinuous. These slip zones tend to form a thin plane in which there is more open space that acts as a channel for water. Some faults tend to fill with broken rock formed as they slip, so they take on a very different flow property from that of the surrounding rock. The proposed repository would be in the Topopah Spring welded tuff in the unsaturated zone, at least 200 meters (660 feet) below the surface and at least 160 meters (530 feet) above the water table (DIRS 154554-BSC 2001, pp. 28-29).

> **HYDROGEOLOGIC TERMS**
>
> **Saturated zone:** The area below the water table where all spaces (fractures and rock pores) are completely filled with water.
>
> **Unsaturated zone:** The area between the surface and the water table where only some of the spaces (fractures and rock pores) are filled with water.
>
> **Matrix:** The solid, but porous, portion of the rock.

When it rains in the Yucca Mountain vicinity, most of the water runs off and a very limited amount infiltrates the rock on the surface of the mountain. Some of the water that remains on the surface or infiltrates the rock evaporates back into the atmosphere (directly or through plant uptake and evapotranspiration). The very small amount of water that infiltrates the rock and does not evaporate percolates down through the mountain to the saturated zone (DIRS 155950-BSC 2001, Section 3.3.2.1, p. 3-17). Water that flowed through the unsaturated zone into the proposed repository could dissolve some of the waste material, if there was a breach in the package containment, and could carry it through the groundwater system to the accessible environment, where exposure to humans could occur.

5.2.2 COMPONENTS OF THE WASTE PACKAGE AND DRIP SHIELD

The waste package would consist of two concentric cylindrical containers sealed with welded lids in which DOE would place the waste forms. The inner cylinder would be stainless steel (316NG). The outer cylinder would be a corrosion-resistant nickel-based alloy (Alloy-22). Alloy-22 would protect the underlying structural material (stainless steel) from corrosion, while the structural material would support the thinner, corrosion-resistant material. The current design calls for emplacement of a titanium drip shield over the waste packages just prior to repository closure. With the drip shield in place, the Alloy-22 outer cylinder would be the second corrosion barrier protecting the waste from contact with water. The use of two distinctly different corrosion-resistant materials would reduce the probability that a single environmental condition could cause the failure of both materials. Before the double-walled waste package was sealed, helium would be added as a fill gas. The helium would prevent corrosion of the waste form and help transfer heat from the waste form itself to the inner wall of the waste package. Moving heat away from the waste form would be one important means of controlling waste form temperatures. This would help preserve the integrity of the metal cladding on the fuel rods, thus extending the life of an already-existing barrier that protects the waste from water.

5.2.3 VISUALIZATION OF THE REPOSITORY SYSTEM FOR ANALYSIS OF LONG-TERM PERFORMANCE

In general, the repository system was modeled as a series of processes linked together, one after the other, spatially from top to bottom in the mountain. From a computer-modeling standpoint, it is important to break the system into smaller portions that relate to the way information is collected. In reality, an operating repository system would be completely interconnected, and virtually no process would be independent of other processes. However, the complexity of such a system demands some idealization of the system for an analysis to be performed.

The first step in the visualization of the system is the development of a listing of all the possible features, events, and processes that could apply to the behavior of the system. An example of a *feature* is the existence of a fault, an example of an *event* is a seismic event (earthquake), and an example of a *process* is the gradual degradation of the waste package wall by general corrosion. The list is then screened using various types of analyses to determine what features, events, and processes should be included in the modeling. The chosen features, events, and processes are then assembled into scenarios, which are descriptions of how features, events, and processes link together to result in a certain outcome (see Appendix I, Section I.2.1, for further detail).

The elements of the TSPA model are organized into the following categories, which are generally related to various parts of the system:

- Unsaturated zone flow
- Engineered barrier system environments
- Waste package and drip shield degradation
- Waste form degradation
- Engineered barrier transport
- Unsaturated zone transport
- Saturated zone flow and transport
- Biosphere

The individual models associated with these elements are discussed in Appendix I, Sections I.2.2 through I.2.9.

In addition, the following special scenarios are also discussed in Appendix I, Sections I.2.10 through I.2.13:

- Volcanism
- Human intrusion
- Nuclear criticality
- Atmospheric radiological transport

During the development of the TSPA model, DOE often had to make assumptions. The main reason for assumptions was to account for situations where there was limited data. With additional data, it may be possible to present a more “realistic” representation, usually as a statistical distribution. If data are limited, it is necessary to make assumptions and use associated conservative data values. The Nuclear Regulatory Commission and Environmental Protection Agency rulemaking processes acknowledged that uncertainty about physical processes acting over the large space and time scales of interest will remain, even after many years of site characterization. The long-term analysis does not seek an exact prediction but rather seeks to establish a representative projection. The list of assumptions is too large to include here. Table 5-3 is an index to a series of tables that describe in detail the assumptions in the model and associated key attributes. The detailed information is in the Total System Performance Assessment-Site Recommendation document (DIRS 153246-CRWMS M&O 2000, pp. F-2 to F-9).

Table 5-3. Cross-reference to key assumptions and associated attributes in the TSPA model.[a]

Category	TSPA-Site Recommendation table[b]
Unsaturated zone flow and transport	F-1
Near-field environment	F-2
Engineered barrier system—chemical environment and radionuclide transport	F-3
Drip shield/waste package	F-4
Inventory component	F-5
In-package chemistry component	F-6
Commercial spent nuclear fuel degradation component	F-7
Defense spent nuclear fuel degradation component	F-8
High-level radioactive waste degradation component	F-9
Dissolved concentration component	F-10
Colloidal concentration component	F-11
Saturated zone flow and transport	F-12
Biosphere	F-13
Disruptive events	F-14

a. Some assumptions were modified in the *Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, all). See Table 1-1 of that document for a summary of areas where assumptions were modified or revised.
b. See DIRS 153246-CRWMS M&O (2000, pp. F-2 to F-9).

5.2.4 UNCERTAINTY

As with any impact estimate, there is a level of uncertainty associated with the forecast, especially when estimating impacts over thousands of years. Uncertainty can be defined as the measure of confidence in the forecast related to determining how a system will operate or respond. The amount of uncertainty associated with an impact estimate is a reflection of several factors, including the following four factors:

- An understanding of the components of a system (such as human and societal, hydrogeologic, or engineered) and how those components interact. The greater the number of components, the more complex the system, the lesser the capability to measure or understand how the system or components produce a greater potential for uncertainty. Similarly, fewer studies or more assumptions produce greater potential for uncertainty.

- The time scale over which estimates are made. Longer time scales for forecasts produce greater potential for uncertainty.

- The available computation and modeling tools. More general computation tools or more assumptions produce greater potential for uncertainty.

- The stability and uniformity (or variability) of the components and system being evaluated. Less stability and uniformity (that is, greater variability) produces a greater potential for uncertainty.

DOE recognizes that uncertainties exist from the onset of an analysis; however, forecasts are valuable in the decisionmaking process because they provide insight based on the best information and scientific judgments available. The following section discusses uncertainties in the context of possible effects on the impact estimates reported in this chapter. The discussion is divided to address:

- Uncertainty associated with societal changes and climate
- Uncertainty associated with currently unavailable data
- Uncertainty associated with models and model parameters

5.2.4.1 Uncertainty Associated with Societal Changes, Climate, and Other Long-Term Phenomena

General guidance on predicting the evolution of society has been provided by the National Academy of Sciences. In its report, *Technical Bases for Yucca Mountain Standards* (DIRS 100018-National Research Council 1995, all), the Committee on Technical Bases for Yucca Mountain Standards concluded that there is no scientific basis for predicting future human behavior. The study recommends policy decisions that specify the use of default (or reference) scenarios to incorporate future human behaviors in compliance assessment calculations. The analysis in this chapter generally follows the recommended approach, using as defaults societal conditions as they exist today and the assumption that populations would remain at their present locations. These assumptions, while appropriate for estimating impacts for comparison with other proposed actions, are not realistic because it is likely that populations will move and change in size. Therefore, DOE has chosen to project population size for 2035 (see Chapter 3, Section 3.1.7.1). If populations were to move closer to or increase in size in the Yucca Mountain groundwater region of influence, the radiation dose and resultant impacts could increase. DOE does not have the means to predict such changes quantitatively with great accuracy; therefore, the analysis does not attempt to quantify the resultant effects on overall impacts. In addition, the analysis does not address the potential benefits from future human activities including improved technology for removing radioactive materials from drinking water or the environment or medical advances such as cures for cancer.

Estimates of future climatic conditions are based on what is known about the past, with consideration given to climate impacts caused by human activities. Calcite in Devils Hole, a fissure in the ground approximately 40 kilometers (25 miles) southeast of Yucca Mountain, provides the best-dated record of climate changes over the past 500,000 years. The record shows continual variation, often with very rapid jumps, between cold glacial climates (for the Great Basin, these are called pluvial periods) and warm interglacial climates similar to the present. Fluctuations average 100,000 years in length (DIRS 153038-CRWMS M&O 2000, Section 6.4.1). The past climate cycles were idealized into a regular cycle of pulses, which were repeated throughout the period of the forecast. This method inherently assumes that the future will repeat the past. However, while current understanding of the causes of climate change allows some confidence in this approach, a considerable amount of conservatism was built into the models to account for possible climate uncertainties. For example, a large range of water fluxes was used to reflect the wide rainfall variations that could occur over thousands and hundreds of thousands of years (DIRS 155950-BSC 2001, Section 3.3.2.6). The analysis assumed that the current climate is the driest it will ever be at Yucca Mountain.

5.2.4.2 Uncertainty Associated with Currently Unavailable Data

Some uncertainties for input parameters or models result from gaps in available data. Such gaps may be due to the status of research (with further data expected later) or conditions that limit gathering of data (such as the need to conduct tests over impractical long periods of time or the necessity to not overly disturb the emplacement site). Uncertainty associated with currently unavailable data is a subset of parameter and model uncertainty that is discussed further in Section 5.2.4.3.

As further discussed in Section 5.2.4.3, the use of parameter distributions and studies of alternative models can provide understanding of how the lack of data affects the range of the impact results. Furthermore, sensitivity studies (see Section 5.2.4.3.4) can also provide insight into the importance of particular parameters. The sensitivity studies sometimes identify data with a small contribution to the results, thereby mitigating concerns arising from their unavailability.

The fact that some data are currently unavailable does not necessarily preclude providing adequate assessment of long-term impacts. When the Draft EIS and the Supplement to the Draft EIS were prepared there was sufficient information to provide an adequate analysis of the long-term performance impacts.

However, additional data have been generated since the publication of those documents. These data have helped improve characterization of the range of impacts in this Final EIS over those reported in the Draft EIS. Some examples of the additional data and their uses are the following:

- Concentrations of chemical components in the rock such as chloride, bromide, and sulfate are being measured, and the results will aid in identifying fast paths for water flow. Ongoing analyses of the isotopic ages of fracture-lining minerals provide preferential information on the history of water movement. These studies show how and when water has moved through the unsaturated zone and reveal characteristics of the water, such as the chemical composition and temperature. This information has been factored into modeling of the unsaturated zone (DIRS 155950-BSC 2001, Section 3.3.2)

- The effects of heating on water seepage into emplacement drifts were investigated in a drift-scale thermal test and by laboratory experiments that support models for predicting the effects of coupled processes over much longer periods (DIRS 155950-BSC 2001, Section 3.3.3)

- Accelerated corrosion testing of Alloy-22 has allowed more definitive quantification of corrosion rates used in improvements in the waste package degradation model (DIRS 155950-BSC 2001, Section 7.2.2)

5.2.4.3 Uncertainty Associated with Models and Model Parameters

The long-term performance model used to assess the impacts from groundwater migration includes a large number of submodels and requires a large amount of input data. The model must account for important features of the system, likely events, and processes that would contribute to the release and migration of materials. Because of the long periods being simulated, the complexity and variability of a natural system, and several other factors, the performance modeling must deal with a large degree of uncertainty. This section discusses the nature of the uncertainties and how they were accounted for in this EIS and their implication to interpretation of impact results. The *Supplemental Science and Performance Analysis* (DIRS 155950-BSC 2001, all) contains further details concerning this subject.

5.2.4.3.1 *Variability Versus Uncertainty*

A variable feature, event, or process is one that changes over space or with time. Examples include the porosity of the rock mass, the temperature in the repository, and the geochemical environment in the repository drifts. If all information was available, such parameters would be best expressed as known mathematical functions of space and time. In contrast, uncertainty relates to a lack of knowledge regarding a feature, event, or process-one whose properties or future outcome cannot be predicted. Four types of uncertainty are typically considered: value uncertainty, *conceptual model* uncertainty, numerical model uncertainty, and uncertainty regarding future events. The treatment of a feature, event, or process as purely variable or purely uncertain can lead to different modeling results.

Uncertainty and variability are sometimes related. The exact nature of the variability in a natural system cannot be known because all parts of the system cannot be observed. For example, DOE cannot dig up all the rock in Yucca Mountain and determine that the positioning of the rock layers is exactly as suggested by core sample data. Therefore, there is uncertainty about the properties of the rock at specific locations in the mountain because properties change with distance and it is not known how much they change at any given location. If the variability can be appropriately quantified or measured, a model usually can be developed to include this variability. If the variability cannot be physically quantified or estimated, it should be treated as uncertainty (lack of knowledge). However, the ability to model some types of spatial variability can be limited not only by lack of data but also by the capacity of a computer to complete calculations (for example, if one simulation took weeks or months to complete). In these instances, variability must be simplified in such a way as to be conservative (that is, the simulation would overestimate the impact).

Two basic tools were used in the analysis to deal with uncertainty and variability: alternative conceptual models and probability theory. Alternative conceptual models were used to handle uncertainty in the understanding of a key physical-chemical process controlling system behavior. Probability theory was used to understand the impacts of uncertainty in specific model parameters (that is, would results change if the parameter value was different). In particular, uncertain processes often required different conceptual models. For example, different conceptual models of how water in fractures communicates with water in the smaller pores or the matrix of the rock in the unsaturated zone lead to different flow and transport models. Sometimes conceptual models are not mutually exclusive (for example, both matrix and fracture flow might occur), and sometimes they do not exhaustively cover all possibilities (apparently matrix and fracture flow do cover all possibilities). These examples indicate that the use of alternative conceptual models, while often necessary to characterize some types of uncertainty, is not always as exact as desired.

A process of weighting alternative conceptual models (as described below) was used in the long-term consequence analysis to account for uncertainties in conceptual models. The Monte Carlo sampling technique was used for handling uncertainty in specific model parameters and for alternative conceptual models that were weighted beforehand with specific probabilities. The method involves random sampling of ranges of likely values, or *distributions*, for all uncertain input parameters. Distributions describe the probability of a particular value in the range. A common type of distribution is the familiar "bell-shaped" curve, also known as the *normal distribution*. Parameters in the consequence analysis are described by many different types of distributions appropriate for how the values and their probabilities are understood. Numerous realizations of the repository system behavior were calculated, each based on one set of samples of all the inputs. Each total system realization had an associated probability so that there is some perspective on the likelihood of that set of circumstances occurring. The Monte Carlo method yields a range for any chosen performance measure (for example, peak annual individual dose in a given period at a given location) along with a probability for each value in the range. In other words, it gives an estimate of repository performance and determines the possible errors based on the estimate. In this chapter, the impact estimates are expressed as the mean of all the realizations and the 95th-percentile value (that is, the value for which 95 percent of the results were smaller).

CALCULATING THE MEAN AND 95TH-PERCENTILE RESULTS

DOE calculated a mean and 95th-percentile dose history by selecting the mean and 95th-percentile value at each time step in the simulation. Thus, the mean dose history consisted of the average of all 300 realizations of dose rate at each time step, and the 95th-percentile dose history consisted of the 95th-percentile at each time step. The EIS analysis determined the peak value from these dose histories, and the EIS discusses the "peak of the mean dose history" and the "peak of the 95th-percentile dose history."

5.2.4.3.2 *Weighting of Alternative Conceptual Models*

In some cases, modeling alternatives form a continuum, and sampling from the continuum of assumptions fits naturally in the Monte Carlo framework of sampling from probability distributions. In other cases, the assumptions or models are discrete choices. In particular, some processes are so highly uncertain that there are not enough data to justify developing continuous probability distributions over the postulated ranges of behavior. In such cases, a high degree of sampling is unwarranted, and an analysis often models two or three cases that are assumed to encompass the likely behavior.

There were two possible approaches to incorporating discrete alternative models in the performance analysis: weighting all models into one comprehensive Monte Carlo simulation (lumping), or keeping the discrete models separate and performing multiple Monte Carlo simulations for each discrete model (splitting). The main results in Section 5.4 were developed using the splitting approach because they were based on a limited range of uncertainty. Based on expert judgment (and to some extent the finite time and resources that could be applied to the analysis effort), the analysis used a best estimate of the more likely ranges of model behavior and parameter ranges. Some alternative models were not included in the analysis, and some parameter ranges of the included models were narrowed. Because of this narrowed range of models and parameters, the results are conditional, meaning that they depend on certain models and parameters being held constant or having their variance restricted. One such condition is the specific design of the repository and the waste packages in the design evaluated in this EIS. Another important condition is that the cladding on the spent nuclear fuel can be depended on as a barrier. Other conditional results were used to characterize the effect of certain assumptions. For example, splitting was done to consider such events as human intrusion (Section 5.7.1), igneous activity (Section 5.7.2), and criticality (Section 5.8). The consequences of these types of events are not part of results given in Section 5.4; rather they are reported as added impacts with certain probabilities of occurrence.

5.2.4.3.3 *Uncertainty and the Proposed Action*

The analysis for the Proposed Action encompassed many of the underlying uncertainties. It included some of all four types of uncertainty: value or parameter uncertainty, conceptual model uncertainty, numerical model uncertainty, and future-event uncertainty. Therefore, the results represent a “lumping” approach. Uncertainty not lumped into the modeling, which produced the central results in Section 5.4, was addressed discretely in alternative models, alternative features, and alternative events such as human intrusion. These alternatives were “split” from the nominal results, and their effects on performance are described separately.

5.2.4.3.4 *Uncertainty and Sensitivity*

In addition to accounting for the uncertainty, characteristics of the engineered and natural systems (such as the unsaturated and saturated zones of the groundwater system) that would have the most influence on repository performance also need to be understood. This information helps define uncertainty in the context of what would most influence the results. This concept is called sensitivity analysis. A number of methods are used to explain the results and quantify sensitivities. Total system performance is a function of sensitivity (if a parameter is varied, how much do the performance measures change) and uncertainty (how much variation of a parameter is reasonable). For example, the long-term performance results could be very sensitive to a certain parameter, but the value for the parameter is exactly known. In the uncertainty analysis techniques described below, that parameter would not be regarded as important. However, many parameters in the analyses do have an associated uncertainty and do become highly important to performance. On the other hand, the level of their ranking can depend on the width of the assigned uncertainty range.

Many of the important uncertain parameters were examined in alternative models. The alternative models either expand the range of the parameters beyond the expected range of uncertainty or change the weighting of the parameter distribution. For example, this type of analysis was performed for alternative models of seepage (DIRS 101779-DOE 1998, Volume 3, pp. 5-1 to 5-9) and cladding degradation (DIRS 101779-DOE 1998, Volume 3, pp. 5-32 to 5-35). An example of alternative model studies for volcanic hazards is discussed in DIRS 155950-BSC (2001, Section 14.3.1, p. 14-6).

System performance could be sensitive to repository design options, but models and parameters for these various options do not have an assigned uncertainty. Therefore, although they can be important, they do not show up as key parameters based on an uncertainty analysis. The determination of the parameters or components that are most important depends on the particular performance measure being used. This point was demonstrated in the 1993 TSPA (DIRS 100111-CRWMS M&O 1994, all; DIRS 100191-Wilson et al. 1994, all) and the Total System Performance Assessment-1995 (DIRS 100198-CRWMS M&O 1995, all). For example, these two analyses showed that the important parameters would be different for 10,000-year peak doses than for 1-million-year peak doses.

There are several techniques for analyzing uncertainties, including the use of qualitative scatter plots where the results (for example, annual individual dose) are plotted against the input parameters and visually inspected for trends. In addition, performance measures can be plotted against various subsystem outputs or surrogate performance measures (for example, waste package lifetime) to determine if that subsystem or performance surrogate would be important to performance. There are several formal mathematical techniques for analyzing the sets of realizations from a Monte Carlo analysis to extract information about the effects of parameters. Such an analysis determined the principal factors affecting the performance of the repository design.

5.2.4.3.5 *Uncertainty Analysis for the TSPA-Site Recommendation*

The Science and Engineering Report (DIRS 153849-DOE 2001, all) provides the results of a comprehensive quantitative analysis of the possible future behavior of a Yucca Mountain repository. The analysis, documented in the *Total System Performance Assessment for the Site Recommendation* (DIRS 153246-CRWMS M&O 2000, all), combined the results of detailed conceptual and numerical models of each of the individual and coupled processes in a single *probabilistic* model that can be used to assess how a repository might perform over long periods. The TSPA-Site Recommendation was a next-generation analysis after the TSPA-Viability Assessment, which DOE used for analysis of long-term performance in the Draft EIS. The Site Recommendation analysis was the result of design changes to the proposed repository and advancement in knowledge from ongoing research activities.

Despite the extensive scientific studies described in the Science and Engineering Report, DOE has always recognized that uncertainties will remain in any assessment of the performance of a repository over thousands of years, as discussed in that report (DIRS 153849-DOE 2001, Sections 1.5, 4.1, and 4.4). These uncertainties are attributable to a variety of causes, ranging from uncertainty regarding the fundamental processes that could affect radionuclide migration to uncertainty related to the design and operation of the repository. For this reason, one part of the DOE approach to dealing with uncertainty relies on multiple lines of evidence that can contribute to the understanding of the performance of the potential repository. Another part of the DOE approach is a commitment to continued testing, monitoring, and analysis beyond the possible recommendation of the site.

The TSPA-Site Recommendation model incorporated a number of uncertainties. These were uncertainties for which a realistic distribution of parameters is not identified, but rather a very conservative bounding value or bounding range was chosen. Additional studies have investigated effects of unquantified uncertainties and sensitivities in the TSPA model by better quantification of uncertainties and the affected processes. This research is documented in the Supplemental Science and Performance Analysis (DIRS 155950-BSC 2001, all). (See Appendix I, Section I.2 for more detailed discussion of the evolution of the TSPA model and application to this EIS.) A summary of areas in which the Supplemental Science and Performance Analysis model benefited from these additional uncertainty studies is provided below. The Supplemental Science and Performance Analysis (DIRS 155950-BSC 2001, all) contains full details of the studies.

Unquantified Uncertainty Analysis

Part of the work described in the Supplemental Science and Performance Analysis (DIRS 155950-BSC 2001, all) included analysis of unquantified uncertainties. Table 5-4 summarizes the elements of the model that DOE studied and indicates whether or not revised model elements were included in the Supplemental Science and Performance Analysis model. The Supplemental Science and Performance Analysis model, with additional modifications, was used for the long-term performance analysis for this

Table 5-4. Analysis of unquantified uncertainties and resulting TSPA model modifications[a] (page 1 of 2).

Process model (section of S&ER[b])	Topic of unquantified uncertainty analysis	Section of SSPA[c] Volume 1	In Supplemental TSPA[d] model
Seepage into emplacement drifts (4.2.1)	Flow- focusing in heterogeneous permeability field; episodic seepage	4.3.1, 4.3.2, 4.3.5	Yes
	Effects on rock bolts and drift degradation on seepage	4.3.3, 4.3.4	
Coupled effects on seepage (4.2.2)	Thermal effects on seepage	4.3.5	Yes
	Thermal-hydrologic-chemical effects on seepage	4.3.6	
Water diversion performance of engineered barrier system (4.2.3)	Multiscale thermal-hydrologic model, including effects of rock dryout	5.3.1	Yes
	Thermal property sets	5.3.1	Yes
	Effect of in-drift convection on temperature, humidity, invert saturations, and evaporation rates	5.3.2	
	Composition of liquid and gas entering drift	6.3.1	Yes
	Evolution of in-drift chemical environment	6.3.3	Yes
In-drift moisture distribution (4.2.5)	Environment on surface of drip shields and waste packages	5.3.2, 7.3.1	
	Condensation under drip shields	8.3.2	
	Evaporation of seepage	8.3.1, 5.3.2	Yes
	Effect of breached drip shields or waste package on seepage	8.3.3	Yes
	Waste package release flow geometry (flow- through, bathtub)	8.3.4	
Drip shield degradation and performance (4.2.4)	Local chemical environment on surface of drip shields (including magnesium, lead) and potential for initiating localized corrosion	7.3.1	
Waste package degradation and performance (4.2.4)	Local chemical environment on surface of waste packages (including magnesium, lead) and potential for initiating localized corrosion	7.3.1	
	Aging and phase stability effects on Alloy-22	7.3.2	Yes
	Uncertainty in weld stress state following mitigation	7.3.3	Yes
	Weld defects	7.3.3	Yes
	Early failure due to improper heat treatment	7.3.6	Yes
	General corrosion rate of Alloy-22: temperature dependency[e]	7.3.5	Yes
	General corrosion rate of Alloy-22: uncertainty/ variability partition	7.3.5	Yes
	Long- term stability of passive films on Alloy-22	7.3.4	
	Stress threshold for initiation of stress corrosion cracking	7.3.3	Yes
	Distribution of crack growth exponent repassivation slope	7.3.7	Yes
In-package environments (4.2.6)	Effect of HLW[f] glass degradation rate and steel degradation rate on in-package chemistry	9.3.1	Yes
Cladding degradation and performance (4.2.6)	Effect of initial perforations, creep rupture, stress corrosion cracking, localized corrosion, seismic failure, rock overburden failure, and unzipping velocity on cladding degradation	9.3.3	Yes
Defense HLW degradation and performance (4.2.6)	HLW glass degradation rates	9.3.1	
Dissolved radionuclide concentrations (4.2.6)	Solubility of neptunium, thorium, plutonium, and technetium	9.3.2	Yes
Colloid-associated radionuclide concentrations (4.2.6)	Colloid mass concentrations	9.3.4	
Engineered barrier system (invert) degradation and transport (4.2.6, 4.2.7)	Diffusion inside waste package	10.3.1	Yes
	Transport pathway from inside waste package to invert	10.3.2	
	Sorption inside waste package	10.3.4	Yes
	Sorption in invert	10.3.4	Yes
	Diffusion through invert	10.3.3	Yes
	Colloid stability in invert	10.3.5	
	Microbial transport of colloids	10.3.6	
Unsaturated zone radionuclide transport (advective pathways; retardation; dispersion; dilution) (4.2.8)	Effect of drift shadow zone-advection/diffusion splitting	11.3.1	Yes
	Effect of drift shadow zone – concentration boundary condition on engineered barrier system release rates	11.3.1	
	Effect of matrix diffusion	11.3.2, 11.3.3	
Saturated zone radionuclide flow and transport (4.2.9)	Groundwater specific discharge	12.3.1	
	Effective diffusion coefficient in volcanic tuffs	12.3.2	
	Flowing interval (fracture) porosity	12.3.2	
	Effective porosity in alluvium	12.3.2	
	Correlation of effective diffusion coefficient with matrix porosity	12.3.2	
	Bulk density of alluvium	12.3.2	Yes
	Retardation for radionuclides irreversibly sorbed on colloids in alluvium	12.3.2	
	Sorption coefficient in alluvium for iodine, technetium	12.3.2	Yes
	Sorption coefficient in alluvium for neptunium, uranium	12.3.2	
	Sorption coefficient for neptunium in volcanic tuffs	12.3.2	
	Effective longitudinal dispersivity	12.3.2	

Table 5-4. Analysis of unquantified uncertainties and resulting TSPA model modifications.[a] (page 2 of 2).

Process model (section of S&ER[b])	Topic of unquantified uncertainty analysis	Section of SSPA[c] Volume 1	In Supplemental TSPA[d] model
Biosphere (4.2.10)[g]	Individual of interest	13.3.1	
	Comparison of dose assessment methods	13.3.2	
	Radionuclide removal from soil by leaching	13.3.3	
	Uncertainties not captured by GENII-S model	13.3.4	
	Influence of climate change on groundwater usage and biosphere dose conversion factors	13.3.5, 13.3.7	

a. Adapted from DIRS 155950-BSC (2001, Table 1-1, pp. 1T-1 to 1T-6).
b. S&ER - Science and Engineering Report (DIRS 153849 - DOE 2001, all).
c. SSPA - Supplemental Science and Performance Analysis (DIRS 155950-BSC 2001, all).
d. TSPA -Total System Performance Assessment.
e. The temperature dependent corrosion model was not used for this EIS (see Appendix I, Section I.4); the model used for this EIS yields a more conservative result.
f. HLW = high-level radioactive waste.
g. DOE used revised biosphere dose conversion factors for this EIS to conform to the Environmental Protection Agency standard, 40 CFR Part 197.

Final EIS (see Appendix I, Sections I.2 and I.4). The first column of Table 5-4 lists the major process models and a reference to the appropriate section in the Science and Engineering Report (DIRS 153849-DOE 2001, all). The second column lists the individual model elements analyzed in the unquantified uncertainties report. The third column lists sections of Volume 1 of the Supplemental Science and Performance Analysis report (DIRS 155950-BSC 2001, all) that contain additional details on the analysis. The analyses included sensitivity studies or other analysis methods to determine how significant the uncertainty might be. If warranted and possible, changes were made to the Supplemental Science and Performance Analysis model to better characterize the uncertainties; this is noted in the fourth column.

5.2.4.3.6 *Key Parameters and Uncertainty*

DOE performed an analysis to determine which parameters contributed most to the uncertainties in the long-term performance results for the nominal scenario reported in Section 5.4. Such important parameters will be the greatest contributors to variations in calculated impacts because of the high sensitivity of the results to the parameter or high uncertainty in the parameter. In any case, the range of values in the distribution for these parameters exerts the strongest influence on the uncertainty of the results.

Two types of analysis were used: stepwise linear rank regression and classification tree [in which parameters were classified in terms of the separation of outcomes into “high”-dose (top 10th-percentile) and “low”-dose (bottom 10th-percentile) categories] (DIRS 155934-Mishra 2001, all; DIRS 155936-Mon 2001, all).

Regression Analysis

Regression analysis is a tool for quantifying the strength of input-output relationships in the TSPA model. To this end, a stepwise linear rank regression model is fitted between individual dose at a given time (or some other performance measure) and all randomly sampled input variables. Parameters are ranked on the basis of how much their exclusion would degrade the explanatory power of the regression model. The importance ranking measure used for this purpose is the uncertainty importance factor, which is defined as the loss in explanatory power divided by the coefficient of determination of the regression model. The uncertainty importance factor quantifies the proportion of the total spread (variance) in total dose explained by the regression model that can be attributed to the variable of interest.

Classification Tree Analysis

Classification tree analysis, a subset of classification and regression tree analysis, is a method for determining variables or interactions of variables that drive output into particular categories. Classification and regression tree analyses can be used to generate decision rules that determine whether a particular realization would produce "high" or "low" dose depending on the values of the most important variables. Unlike regression analysis, which is based on the total range of model outcomes, classification tree analysis focuses on extreme values of model results and tries to relate them to specific ranges of values for the important variables.

Results

For different time frames in the analysis, different parameters emerge as important to the overall variability of the results (DIRS 155934-Mishra 2001, all and DIRS 155936-Mon 2001, all). Table 5-5 lists the results of the analysis.

Table 5-5. Top-ranking uncertainty importance parameters.[a]

Time after closure	Two most important parameters
125,000 years	General humid air corrosion rate of Alloy-22 outer lid
	General humid air corrosion rate of Alloy-22 inner lid
250,000 years	General humid air corrosion rate of Alloy-22 outer lid
	General humid air corrosion rate of Alloy-22 inner lid
500,000 years	Episodic factor
	General humid air corrosion rate of Alloy-22 outer lid
1,000,000 years	Episodic factor
	Infiltration scenario

a. Sources: DIRS 155934-Mishra (2001, all) and DIRS 155936-Mon (2001, all).

A description of the important parameters identified in Table 5-5 follows:

- *General Humid Air Corrosion Rates of Alloy-22, Inner and Outer Lids* – When the drip shields are intact and no water is dripping on the waste package, the corrosion rate of Alloy-22 is governed by the humid air corrosion rates of the inner lid and the outer lid. The waste package closure end has three lids: an innermost stainless-steel lid, an inner Alloy-22 lid, and an outer Alloy-22 lid. These two corrosion rate parameters govern how the respective Alloy-22 lids degrade when not exposed to dripping water.

- *Episodic Factor* – The conceptual model governing episodic infiltration represents fractures comprised of randomly distributed "pinch-point" and "storage" apertures. Pinch-point apertures act as capillary barriers to the infiltration of water, which accumulates in a volume above the pinch-point dictated by the storage aperture. The water continues to accumulate in the storage aperture until the hydraulic head above the pinch-point aperture exceeds the associated capillary rise height. Once this threshold is reached, the water begins to flow downward under the force of gravity at a rate dictated by the permeability of the aperture. Water continues to flow through the aperture until the accumulated water is completely drained. This behavior leads to an episodic infiltration of water through fractured rock that occurs randomly in space and time. The distribution of a factor that is randomly sampled governs this episodic flow in the numerical model.

- *Infiltration Scenario* – For each of the six *climate states* (see Appendix I, Section I.2.2) there are three possible infiltration rates (low, medium, and high). The particular climate state and infiltration rate is the infiltration scenario. Therefore, this variable is a function of the infiltration rate.

The parameters in Table 5-5 that most affect the total uncertainty in the TSPA model are factors that would govern the degradation of the waste package for the first 250,000 years following repository closure. After 250,000 years, most waste packages would have failed and other factors become important. Even at 500,000 years after repository closure, waste package degradation is still important. At later times the important parameters would be related to factors that influenced the flow of water in the drifts, especially infiltration and episodic flow.

5.3 Locations for Impact Estimates

Yucca Mountain is in the transition area between the Mojave Desert and the Great Basin. This is a semiarid region with linear mountain ranges and intervening valleys, with rainfall averaging between about 100 and 250 millimeters (4 and 10 inches) a year, sparse vegetation, and a small population. Although there is low infiltration of water through the mountain and no people currently live in the land withdrawal area, radioactive and chemically toxic materials released from the repository could affect persons living closer to the proposed repository in the distant future. This section describes the regions where possible human health impacts could occur.

Figure 5-3 is a map with arrows showing the general direction of groundwater movement from Yucca Mountain. Shading indicates major areas of groundwater discharge through a combination of springs and evapotranspiration by plants. The general path of water that infiltrates through Yucca Mountain is south toward Amargosa Valley, into and through the area around Death Valley Junction in the lower Amargosa Desert. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa (DIRS 100376-Czarnecki 1990, pp. 1 to 12), and spring discharge in Death Valley is a possibility (DIRS 100131-D'Agnese et al. 1997, pp. 64 and 69).

Although groundwater from the Yucca Mountain vicinity flows under and to the west of Ash Meadows in the volcanic tuff or alluvial aquifers, the surface discharge areas at Ash Meadows and Devils Hole (see map in Figure 5-3 for locations) are fed from the carbonate aquifer. While these two aquifers are connected at some locations, the carbonate aquifer has a hydraulic head that is higher than that of the volcanic or alluvial aquifers. Because of this pressure difference, water from the volcanic aquifer does not flow into the carbonate aquifer; rather, the reverse occurs. Therefore, contamination from Yucca Mountain is not likely to mix with the carbonate waters and discharge to the surface at Ash Meadows or Devils Hole (DIRS 104983-CRWMS M&O 1999, all) under current conditions. This pressure difference could change under future climate conditions.

Because, under expected conditions, there would be no contamination of this discharge water, there would be no human health impacts. Furthermore, there would be no consequences to the endangered Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*) or Devils Hole pupfish (*Cyprinodon diabolis*) at those locations.

Figure 3-25 in Chapter 3 shows the projected population of 76,000 residents within 80 kilometers (50 miles) of Yucca Mountain in 2035. This map provides the information used to estimate population doses from radionuclides released to the atmosphere from the repository. The atmospheric analysis in Section 5.5 used the 80-kilometer (50-mile) population distribution described in Section 3.1.8.

In the Draft EIS, impacts were evaluated at 5-kilometer (3-mile), 20-kilometer (12-mile), and 30-kilometer (19-mile) distances from the repository as well as at the groundwater discharge point. The EPA regulation, 40 CFR 197.12 establishes a controlled area around the repository that must not extend farther south than 36 degrees, 40 minutes, 13.6661 north latitude, in the predominant direction of groundwater flow. For this EIS, DOE assumed the controlled area boundary to be the farthest point south. The predominant groundwater flow crosses this boundary approximately 18 kilometers (11 miles) from the repository. Therefore, the 5-kilometer (3-mile) distance would be inside the controlled area, would no longer be part of the accessible environment, and DOE did not evaluate impacts at this distance.

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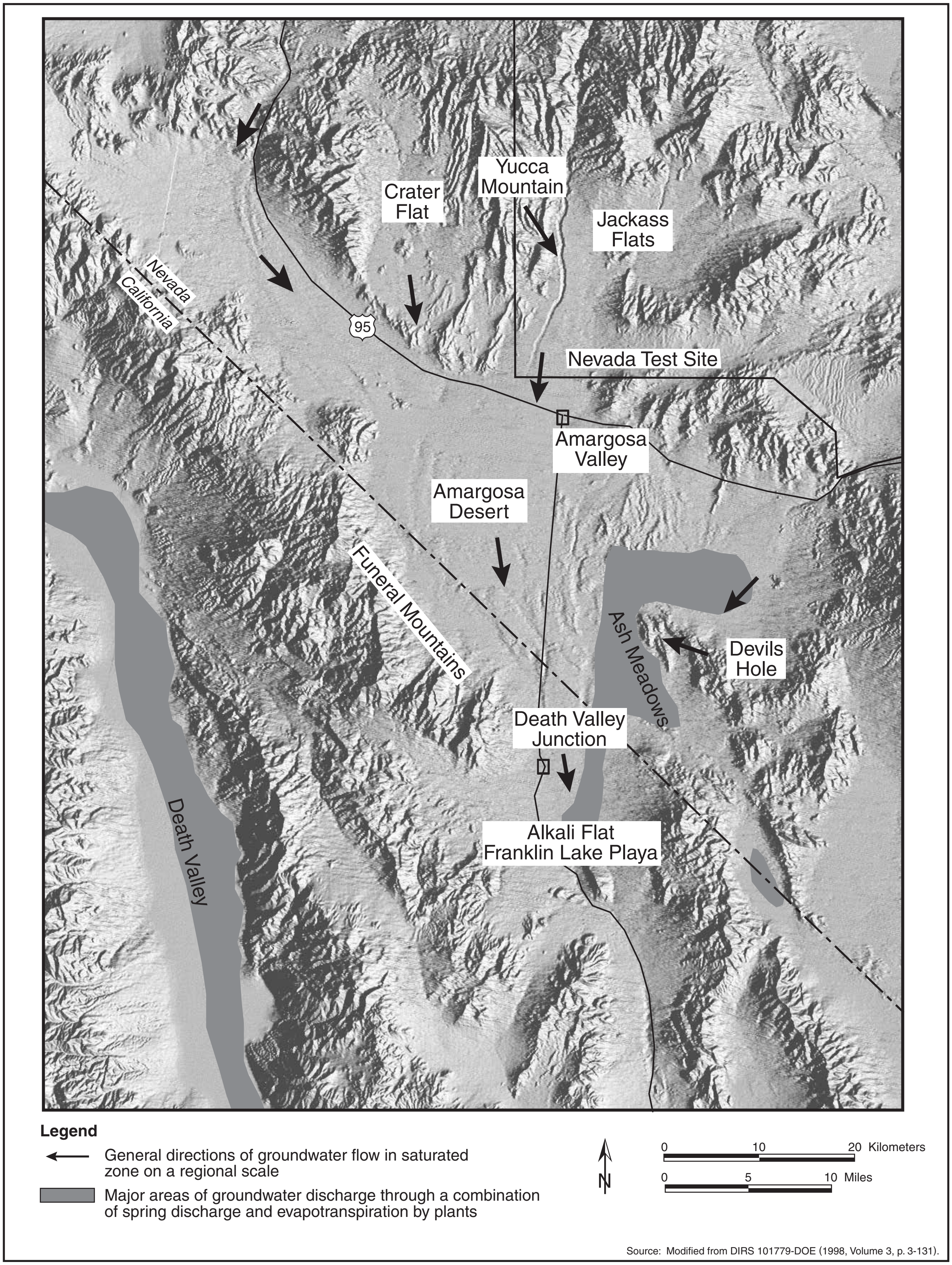

Figure 5-3. Map of the saturated groundwater flow system.

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5.4 Waterborne Radiological Consequences

> **POPULATION DOSE AND FUTURE POPULATION SIZE**
>
> *Population dose* is a summation of the doses received by individuals in an exposed population (unit of measure is *person-rem*). The population dose depends on the number of people at different locations. If the number of people increases in the future, the population dose estimate would also increase.

The following sections report the annual committed effective dose equivalent, expressed in millirem, to individuals living at three locations south of Yucca Mountain. These individuals are assumed to use contaminated groundwater and have lifestyle characteristics of the RMEI defined in 40 CFR 197.21. The RMEI is exposed to the high end of the range of potential dose distribution for the exposed population, called "reasonable maximum exposure" conditions. RMEI is a hypothetical person who meets the following criteria:

a) Lives at the location above where the highest concentration of radionuclides in the groundwater contamination plume crosses the boundary of the controlled area. The surface of the controlled area is defined as (40 CFR Part 197) the area, identified by passive institutional controls, that encompasses no more than 300 square kilometers. It must not extend farther south than 36º 40' 13.661" north latitude, in the predominant direction of groundwater flow, and no more than five kilometers from the repository footprint in any other direction

b) Has a diet and living style representative of the people who now reside in the Town of Amargosa Valley, Nevada. DOE must use projections based on surveys of the people residing in the Town of Amargosa Valley, Nevada, to determine their current diets and living styles and use the mean values of these factors in the assessments conducted for 40 CFR 197.20 and 197.25

c) Drinks 2 liters of water per day from wells drilled into the ground at the location specified in a).

While the RMEI is a regulatory definition for a specific location, impacts to individuals at two additional locations were evaluated using the lifestyle characteristics of the RMEI.

The analysis converted the annual committed effective dose equivalent, referred to as the annual individual dose, to the probability of contracting a fatal cancer (referred to as a latent cancer fatality) due to exposure to radioactive materials in the water. In addition, the analysis calculated population doses in person-rem for two different periods: for the 70-year lifetime at the time of the peak dose during the first 10,000 years after repository closure, and integrated over the first 10,000 years after repository closure. The analysis also converted the population dose to the expected number of latent cancer fatalities in the population. DOE based the analysis on the radionuclide inventories discussed in Section 5.1. However, the analysis included the entire carbon-14 inventory of the commercial spent nuclear fuel as a solid in the groundwater release models. Actually, 2 percent of the carbon-14 exists as a gas in the fuel (see Section 5.5). Thus, the groundwater models slightly overestimate (by 2 percent) the potential impacts from carbon-14.

The analysis studied potential consequences to individuals at three impact locations arising from waste mobilization and waterborne transport. A set of 300 model simulations were run using the GoldSim model (DIRS 155182-BSC 2001, all) for the RMEI location [about 18 kilometers (11 miles) from Yucca Mountain]. Each simulation used separate sets of sampled uncertainty parameters and generated an annual individual-dose profile for the 1 million years following repository closure. This set of simulations for the RMEI location, and some additional groundwater simulations (DIRS 154659-BSC 2001, Enclosure 3) provided the basis for calculating doses at 30 kilometers (19 miles) from the repository and at the discharge location near Franklin Lake Playa.

5.4.1 EXTENSION OF GROUNDWATER IMPACTS TO OTHER DISTANCES

The TSPA model estimates potential groundwater impacts for the RMEI location. This EIS provides groundwater impacts for two other important downgradient locations. These locations are 30 kilometers (19 miles), where most of the current population in the groundwater flow path is located, and 60 kilometers (37 miles), where the aquifer discharges to the surface (this location is also known as Franklin Lake Playa). The TSPA model used for the groundwater impacts at 18 kilometers (11 miles) is specifically designed for the RMEI location and is not directly usable to obtain reasonable estimates at farther distances. This is because conservative assumptions were embodied in the model, and the saturated zone transport model was designed primarily for the volcanic aquifer with characteristically very low mixing of waste in groundwater. Groundwater flow beyond the RMEI location occurs primarily in an alluvial medium with characteristically higher mixing, so plume concentrations would be reduced and a smaller quantity of radionuclides would be carried into the water usage wells.

Appendix I, Section I.4.5, details the development of distance scale factors using a three-dimensional analytical advection and dispersion transport model. Scaling factors were developed based on two criteria: attenuation of the peak concentrations in the plume and general increase in the cross-sectional area of the plume (that is, reduction of the average plume concentration). Two sets of factors were developed based on a large source size (characteristic of the repository footprint) and a small source size [10 meters by 10 meters (33 feet by 33 feet)]. The scaling factors were used to estimate *peak of the mean* and peak of the 95th-percentile annual individual doses and the groundwater concentrations at the two additional distances reported in Sections 5.4.2.1 and 5.4.2.2.

For the 10,000-year period of the nominal scenario, the dose would be attributable to the failure of a few waste packages. In this case, scaling factors based on a small size source were used. For the 1-million-year period, the release would be attributable to general releases over the whole repository area, so large source size scale factors were used. The factors based on the cross-section of the plume were chosen for the estimates. This was appropriate because the effect of water usage by the communities would be to cause significant mixing, and the more characteristic parameter would be the plume average concentration. Appendix I, Section I.4.5, includes scale factors for both approaches for comparison.

5.4.2 WATERBORNE RADIOLOGICAL RESULTS

This section discusses waterborne radiological consequences in relation to a higher-temperature repository operating mode and a lower-temperature operating mode. The individual and population dose calculations in this section were performed in a probabilistic manner using a volume of water necessary to operate 15 to 25 farms, representing a range of groundwater volumes from 1.1 million cubic meters to 4.2 million cubic meters (890 acre-feet to 3,400 acre-feet) with an average water demand of approximately 2.5 million cubic meters (2,000 acre-feet) per year. The final Nuclear Regulatory Commission regulations regarding a Yucca Mountain Repository state that the RMEI calculations should use an average water demand of 3,000 acre-feet [10 CFR 63.312(c)]. The 3.7-million-cubic-meter (3,000 acre-foot) water demand as specified by the Commission would result in dose estimates about two-thirds of the values in this section (DIRS 156743-Williams 2001, Section 6.3, pp. 12 and 13). The groundwater protection calculations in this section use 3,000 acre-feet water demand as called for in 40 CFR 197.12.

5.4.2.1 Waterborne Radiological Results for the Higher-Temperature Repository Operating Mode

The performance analysis indicated that for the first 10,000 years there would be very limited releases, attributable to early waste package failures due to waste package manufacturing defects, with very small radiological consequences (see Table 5-6). For the first 10,000 years after repository closure, the mean

Table 5-6. Impacts for an individual from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode.

Individual	Mean: Peak annual individual dose (millirem)	Mean: Time of peak (years)	Mean: Probability of an LCF[a]	95th-percentile: Peak annual individual dose (millirem)	95th-percentile: Time of peak (years)	95th-percentile: Probability of an LCF[a]
At RMEI location[b]	0.00002[c]	4,900	6×10^{-10}	0.0001[d]	4,900	4×10^{-9}
At 30 kilometers[e]	~0[f]	NC[g]	~0	~0[f]	NC	~0
At discharge location[h]	~0[f]	NC	~0	~0[f]	NC	~0

a. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).
b. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository. The maximum allowable peak of the mean annual individual dose for 10,000 years at this distance is 15 millirem.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. 30 kilometers = 19 miles.
f. Values would be lower than the small values computed for the RMEI location.
g. NC = not calculated (peak time would be greater than time given for the RMEI location).
h. 60 kilometers (37 miles) at Franklin Lake Playa.

WHY ARE THE MEAN IMPACTS SOMETIMES HIGHER THAN THE 95TH-PERCENTILE IMPACTS?

The *mean* impact is the arithmetic average of the 300 impact results from simulations of total-system performance. The mean is not the same as the 50th-percentile value (the 50th-percentile value is called the *median*) if the distribution is *skewed*.

The performance results reported in this EIS come from highly skewed distributions. In this context, *skewed* indicates that there are a few impact estimates that are much larger than the rest of the impacts. When a large value is added to a group of small values, the large value dominates the calculation of the mean. The simulations reported in this EIS have mean impacts that are occasionally above the 90th-percentile and occasionally above the 95th percentile.

peak would be 0.00002 millirem and the 95th-percentile peak would be 0.0001 millirem. The peaks would be even smaller at greater distances. This result was lower than the Environmental Protection Agency standard, which allows up to a 15-millirem annual committed effective dose equivalent during the first 10,000 years. In the remainder of this chapter, the "annual committed effective dose equivalent" is referred to as the "annual individual dose."

Table 5-7 lists the population consequences associated with the peak annual individual dose listed in Table 5-6. The population size was based on the projected population numbers for 2035 in Figure 3-25 in Chapter 3 of this EIS. For these calculations, the analysis assumed that no contaminated groundwater would reach populations in any regions to the north of Yucca Mountain. Therefore, populations in the sectors north of the due east and due west sectors in Figure 3-25 were not considered to be exposed.

- 47 people would be exposed at the RMEI location [includes sectors from 12 to 28 kilometers (7 to 17 miles)]

- 4,200 people would be exposed at about 30 kilometers (19 miles) downgradient from the potential repository [includes sectors from 28 to 44 kilometers (17 to 27 miles)]

Table 5-7. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode.

	Mean		95th-percentile	
Impact	Population dose (person-rem)	Population LCF[a]	Population dose (person-rem)	Population LCF[c]
Peak 70-year lifetime	0.006	0.000003	0.04	0.00002
Integrated over 10,000 years	0.5	0.0002	0.6	0.0003

a. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).

- 69,500 people would be exposed at the discharge location about 60 kilometers (37 miles) downgradient from the potential repository [includes sectors from 44 to 80 kilometers (27 to 50 miles)]

Thus, approximately 74,000 people would be exposed to contaminated groundwater. This stylized population dose analysis assumed that people would continue to live in the locations being used at present. This assumption is consistent with the recommendation made by the National Academy of Sciences (DIRS 100018-National Research Council 1995, all) because it is impossible to make accurate predictions of lifestyles and residence locations far into the future.

The values in Table 5-7 include a scaling factor for water use. The performance assessment transport model calculated the annual individual dose assuming the radionuclides dissolved in water that flowed through the unsaturated zone of Yucca Mountain would mix in an average of 2.4 million cubic meters (1,940 acre feet) (DIRS 155950-BSC 2001, p. 13-42) per year in the saturated zone aquifer. This compares to an annual water use in the Amargosa Valley of about 17.1 million cubic meters (13,900 acre-feet) (DIRS 155950-BSC 2001, p. 13-42). The analysis diluted the concentration of the nuclides in the 2.4 million cubic meters of water throughout the 17.1 million cubic meters of water before calculating the population dose.

The small consequences listed in Tables 5-6 and 5-7 would result from the durability of the waste packages; most of which would remain intact significantly longer than 10,000 years. The outer layer of the waste package would be subject to a very low average corrosion rate, but there is a high degree of uncertainty in the value of that average corrosion rate. Model simulations incorporated a small number of waste package failures within 10,000 years due to manufacturing defects; the dose results in Tables 5-6 and 5-7 during this period would result directly from these early failures.

The radionuclides that would contribute the most to individual dose in 10,000 years would be technetium-99, carbon-14 dissolved in groundwater, and iodine-129. For example, the mean consequence at 18 kilometers (11 miles) has technetium-99 contributing 77 percent of the total annual individual dose rate, carbon-14 contributing 16 percent, and iodine-129 contributing 7 percent. While the atmospheric analysis in this EIS assumed that 2 percent of the carbon-14 migrated as gas in the form of carbon dioxide (see Section 5.5 for more details), the groundwater modeling for this waterborne radiological consequences analysis conservatively assumed that all of the carbon-14 migrated in the groundwater.

Table 5-8 lists impacts for the post-10,000-year period. The table lists the mean and 95th-percentile peak annual individual dose and the times of the associated peaks at three locations. The mean and 95th-percentile annual individual doses during 1 million years following repository closure are shown in Figure 5-4. The multiple peaks occurring 200,000 years or more after repository closure are driven by transitions between climate states.

Table 5-8. Impacts for an individual from groundwater releases of radionuclides during 1 million years after repository closure for the higher-temperature repository operating mode.

Individual	Mean: Peak annual individual dose (millirem)	Mean: Time of peak (years)	95th-percentile: Peak annual individual dose (millirem)	95th-percentile: Time of peak (years)
At RMEI location[a]	150[b]	480,000	620[c]	410,000
At 30 kilometers[d]	100[e]	NC[f]	420[e]	NC
At discharge location[g]	59[e]	NC	240[e]	NC

a. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
d. 30 kilometers = 19 miles.
e. Estimated using scale factors as described in Section 5.4.1.
f. NC = not calculated (peak time would be greater than time given for the RMEI location).
g. 60 kilometers (37 miles) at Franklin Lake Playa.

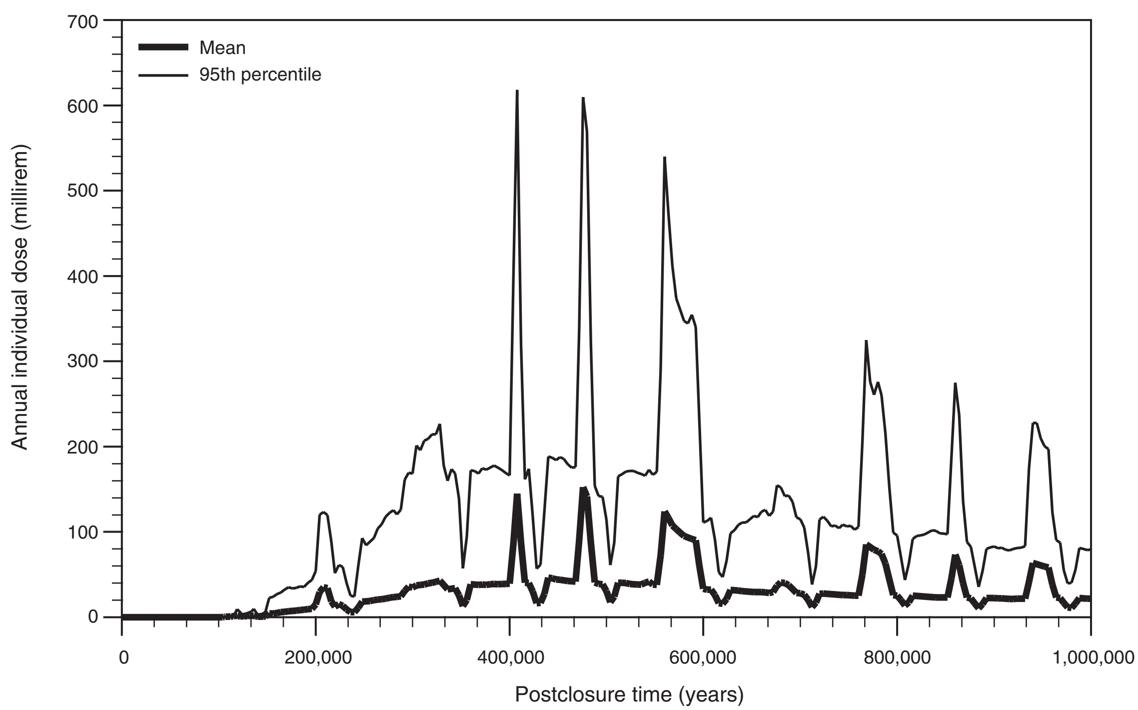

Figure 5-4. Mean and 95th-percentile (based on 300 simulations of total system performance, each using random samples of uncertain parameters) annual individual dose at the RMEI location during 1 million years after repository closure for the nominal scenario under the higher-temperature repository operating mode.

The simulations were ended after 1 million years largely because further radioactive decay would continue to decrease the annual individual dose even for very long-lived radionuclides. The peak annual individual dose usually coincided with the occurrence of a wetter climate period.

The radionuclides that would contribute the most to the peak annual individual dose in 1 million years would be neptunium-237 and plutonium-242. The mean peak annual individual dose at the RMEI location would have neptunium-237 contributing 61 percent of the total annual individual dose, plutonium-242 contributing 13 percent, actinium-227 contributing 5 percent, thorium-229 and uranium-234 each contributing 3 percent, and uranium-233, lead-210, and radium-226 each contributing 2 percent. The plutonium isotopes contributing to dose would be due to colloidal transport of plutonium, not transport of plutonium as a dissolved element in groundwater.

With respect to the groundwater protection standards in 40 CFR 197.30, both the mean and 95th-percentile estimated levels during the 10,000-year regulatory period would be hundreds of thousands of times less than the regulatory limits (see Table 5-9).

Table 5-9. Comparison of nominal scenario long-term consequences at the RMEI location[a] to groundwater protection standards during 10,000 years following repository closure for the higher-temperature repository operating mode.

Radionuclide or type of radiation emitted	EPA limit[b]	Mean peak[c]	95^{th}-percentile peak[d]
Combined radium-226 and radium-228[e] (picocuries per liter)	5	1.0 (1×10^{-11})[f]	1.0 (2×10^{-11})[f]
Gross alpha activity (including radium-226 but excluding radon and uranium)[e] (picocuries per liter)	15	0.4 (2×10^{-8})[f]	0.4 (1×10^{-8})[f]
Combined beta- and photon-emitting radionuclides,[g] millirem per year to the whole body or any organ,[h] based on drinking 2 liters[i] of water per day from the representative volume	4	2×10^{-5}	1×10^{-4}

a. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Environmental Protection Agency limits at 40 CFR 197.30.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. Includes natural background radiation.
f. Value in parentheses is the incremental increase over background radiation that would be attributable to the potential repository.
g. Does not include natural background radiation.
h. This represents a bounding (overestimate) of the maximum dose to any organ because the different radionuclides would affect different organs preferentially.
i. 2 liters = 0.53 gallon.

5.4.2.2 Waterborne Radiological Results for the Lower-Temperature Repository Operating Mode

DOE conducted performance studies for the lower-temperature repository operating mode. This section discusses groundwater impacts for the lower-temperature operating mode. The performance analysis indicated that for the first 10,000 years there would be very limited releases, attributable to early waste package failures due to waste package manufacturing defects, with very small radiological consequences (see Table 5-10). For the first 10,000 years after repository closure, the mean peak would be 0.00001 millirem and the 95th-percentile peak would be 0.0001 millirem. The peaks would be even smaller at greater distances. This result was compared to the EPA standard, which allows up to a 15-millirem annual individual dose during the first 10,000 years.

Table 5-11 lists the population consequences associated with the peak annual individual dose listed in Table 5-10. The population size was based on the population numbers projected for the year 2035 in Figure 3-25 in Chapter 3 of this EIS. For these calculations, the analysis assumed that no contaminated groundwater would reach populations in any regions to the north of Yucca Mountain. Therefore, populations in the sectors north of the due east and due west sectors in Figure 3-25 were not considered to be exposed.

Table 5-10. Impacts for an individual from groundwater releases of radionuclides during 10,000 years after repository closure for the lower-temperature repository operating mode.

Individual	Mean: Peak annual individual dose (millirem)	Mean: Time of peak (years)	Mean: Probability of an LCF[a]	95th-percentile: Peak annual individual dose (millirem)	95th-percentile: Time of peak (years)	95th-percentile: Probability of an LCF[a]
At RMEI location[b]	0.00001[c]	3,400	4×10^{-10}	0.0001[d]	5,000	3×10^{-9}
At 30 kilometers[e]	~0[f]	NC[g]	~0	~0[f]	NC	~0
At discharge location[h]	~0[f]	NC	~0	~0[f]	NC	~0

a. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).
b. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository. The maximum allowable peak of the mean annual individual dose for 10,000 years at this location is 15 millirem.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. 30 kilometers = 19 miles.
f. Values would be lower than the small values computed for the RMEI location.
g. NC = not calculated (peak time would be greater than time given for the RMEI location).
h. 60 kilometers (37 miles) at Franklin Lake Playa.

Table 5-11. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the lower-temperature repository operating mode.

Impact	Mean: Population dose (person-rem)	Mean: Population LCF[a]	95th-percentile: Population dose (person-rem)	95th-percentile: Population LCF[c]
Peak 70-year lifetime	0.004	0.000002	0.03	0.00002
Integrated over 10,000 years	0.3	0.0002	0.4	0.0002

a. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).

- 47 people would be exposed at the RMEI location (includes sectors from 12 to 28 kilometers)
- 4,200 people would be exposed at about 30 kilometers (19 miles) downgradient from the potential repository (includes sectors from 28 to 44 kilometers)
- 69,500 people would be exposed at the discharge location about 60 kilometers (37 miles) downgradient from the potential repository (includes sectors from 44 to 80 kilometers)

Thus, approximately 74,000 people would be exposed to contaminated groundwater. This stylized population dose analysis assumed that people would continue to live in the locations being used at present. This assumption is consistent with the recommendation made by the National Academy of Sciences (DIRS 100018-National Research Council 1995, all) because it is impossible to make accurate predictions of lifestyles and residence locations far into the future.

The values in Table 5-11 include a scaling factor for water use. The performance assessment transport model calculated the annual individual dose assuming the radionuclides dissolved in water that flowed through the unsaturated zone of Yucca Mountain would mix in an average of 2.4 million cubic meters (1,940 acre-feet) (DIRS 155950-BSC 2001, p. 13-42) per year in the saturated zone aquifer. This compares to an annual water use in the Amargosa Valley of about 17.1 million cubic meters (13,900 acre-feet) (DIRS 155950-BSC 2001, p. 13-42). The analysis diluted the concentration of the nuclides in the 2.4 million cubic meters of water throughout the 17.1 million cubic meters of water before calculating the population dose.

The small consequences listed in Tables 5-10 and 5-11 would result from the durability of the waste packages; most of which would remain intact significantly longer than 10,000 years. The outer layer of the waste package would be subject to a very low average corrosion rate, but there is a high degree of uncertainty in the value of that average corrosion rate. Model simulations incorporated a small number of waste package failures within 10,000 years due to manufacturing defects; the dose results in Table 5-10 and 5-11 during this period would result directly from these early failures.

The radionuclides that would contribute the most to individual dose in 10,000 years would be technetium-99, carbon-14 dissolved in groundwater, and iodine-129. For example, the mean consequence at 18 kilometers (11 miles) has technetium-99 contributing 63 percent of the total individual dose rate, carbon-14 contributing 25 percent, and iodine-129 contributing 10 percent. While the atmospheric analysis in this EIS assumed that 2 percent of the carbon-14 migrated as gas in the form of carbon dioxide (see Section 5.5 for more details), the groundwater modeling for this waterborne radiological consequences analysis conservatively assumed that all of the carbon-14 migrated in the groundwater.

Table 5-12 lists impacts for the post-10,000-year period as peak annual doses. The table lists the mean and 95th-percentile peak annual individual dose and the times of the associated peaks at three locations. The mean and 95th-percentile annual individual doses during 1 million years following repository closure are shown in Figure 5-5. The multiple peaks occurring 200,000 years or more after repository closure are driven by transitions between climate states.

Table 5-12. Impacts for an individual from groundwater releases of radionuclides during 1 million years after repository closure for the lower-temperature repository operating mode.

Individual	Mean		95th-percentile	
	Peak annual individual dose (millirem)	Time of peak (years)	Peak annual individual dose (millirem)	Time of peak (years)
At RMEI location[a]	120[b]	480,000	510[c]	410,000
At 30 kilometers[d]	83[e]	NC[f]	350[e]	NC
At discharge location[g]	48[e]	NC	240[e]	NC

a. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
d. 30 kilometers = 19 miles.
e. Estimated using scale factors as described in Section 5.4.1.
f. NC = not calculated (peak time would be greater than time given for the RMEI location).
g. 60 kilometers (37 miles) at Franklin Lake Playa.

The simulations were ended after 1 million years largely because further radioactive decay would continue to decrease annual individual dose even for very long-lived radionuclides. The peak annual individual dose usually coincided with the occurrence of a wetter climate period.

The radionuclides that would contribute the most to the peak annual individual dose in 1 million years would be neptunium-237 and plutonium-242. The mean peak dose at 18 kilometers (11 miles) would have neptunium-237 contributing 63 percent of the total individual dose rate, plutonium-242 contributing 12 percent, actinium-227 contributing 5 percent, thorium-229 and uranium-234 each contributing 3 percent, and uranium-233, lead-210, and radium-226 each contributing 2 percent. The plutonium isotopes contributing to dose would be due to colloidal transport of plutonium, not transport of plutonium as a dissolved element in groundwater.

With respect to the groundwater protection standards in 40 CFR 197.30, both the mean and 95th-percentile estimated levels during the 10,000-year regulatory period would be hundreds of thousands of times less than the regulatory limits (see Table 5-13).

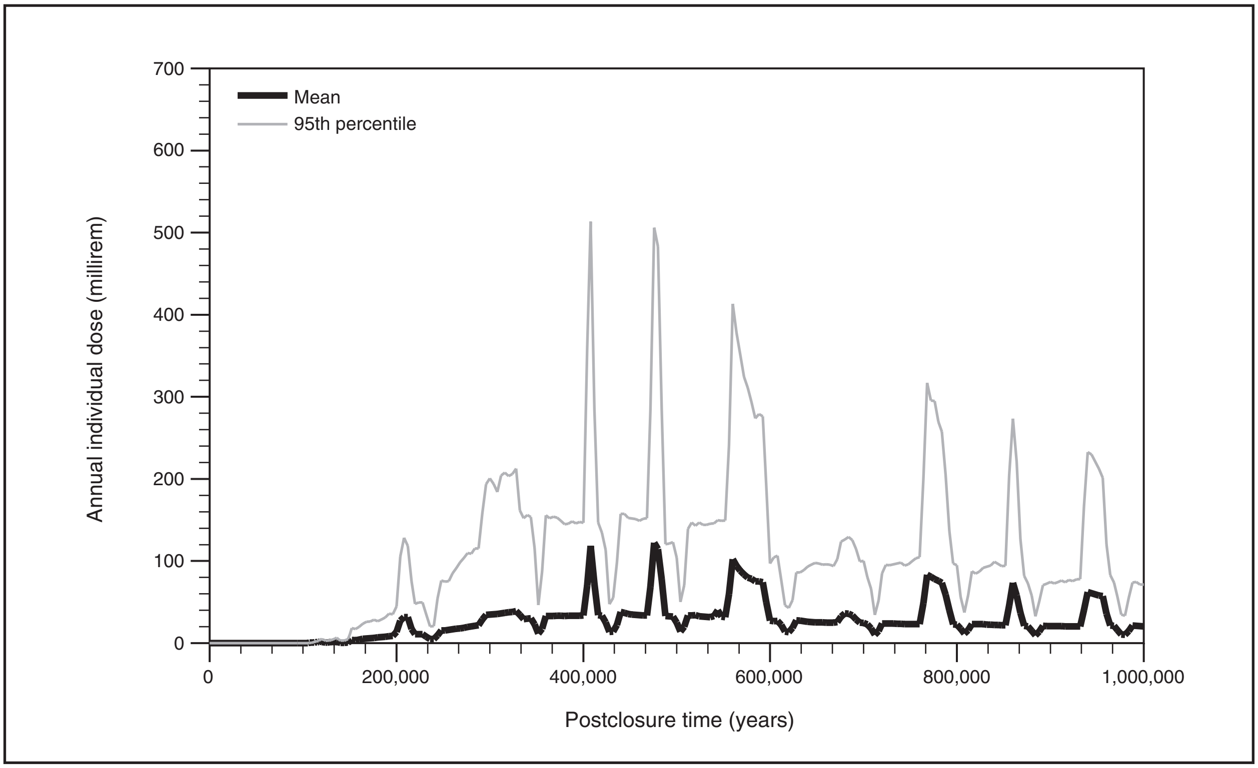

Figure 5-5. Mean and 95th-percentile (based on 300 simulations of total system performance, each using random samples of uncertain parameters) annual individual dose at the RMEI location during 1 million years after repository closure for the nominal scenario under the lower-temperature repository operating mode.

Table 5-13. Comparison of nominal scenario long-term consequences at the RMEI location[a] to groundwater protection standards during 10,000 years following repository closure for the lower-temperature repository operating mode.

Radionuclide or type of radiation emitted	EPA limit[b]	Mean peak[c]	95^{th}-percentile peak[d]
Combined radium-226 and radium-228[e] (picocuries per year)	5	1 (2×10^{-12})[f]	1 (1×10^{-11})[f]
Gross alpha activity (including radium-226 but excluding radon and uranium)[e] (picocuries per year)	15	0.4 (3×10^{-8})[f]	0.4 (2×10^{-8})[f]
Combined beta- and photon-emitting radionuclides,[g] millirem per year to the whole body or any organ,[h] based on drinking 2 liters[i] of water per day from the representative volume	4	1×10^{-5}	7×10^{-5}

a. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Environmental Protection Agency limits set forth in 40 CFR 197.30.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. Includes natural background radiation.
f. Value in parentheses is the incremental increase over background radiation that would be attributable to the potential repository.
g. Does not include natural background radiation.
h. This represents a bounding (overestimate) of the maximum dose to any organ because the different radionuclides would affect different organs preferentially.
i. 2 liters = 0.53 gallon.

5.4.2.3 Alternative Dosimetry Methods

The long-term postclosure groundwater impacts are estimated using ICRP-30 (DIRS 110386-ICRP 1979, all; DIRS 110351-ICRP 1980, all; DIRS 110352-ICRP 1981, all) domestic methods. It has been suggested by an international peer review that the more recent ICRP-72 methods (DIRS 152446-ICRP 1996, all), as are used internationally for such estimates, would be more appropriate. Sensitivity studies indicate the peak dose estimates would be about a factor of 4 lower if the ICRP-72 analytical methods were applied (DIRS 157151-BSC 2001, Appendix L. pp. L-31 to L-33).

5.5 Atmospheric Radiological Consequences

After DOE closed the repository, there would be limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. Still, the rock is porous and does allow gas to flow, so the analysis must consider possible airborne releases. The only radionuclide in the analysis after screening with a potential for gas transport is carbon-14 in the form of carbon dioxide. Iodine-129 can exist in a gas phase, but DOE expects it would dissolve in the groundwater rather than migrate as a gas. The solubility of iodine-129 is a great deal higher than that of carbon dioxide, and the water is already saturated in carbon dioxide because of interaction with carbonate rocks. After the carbon-14 escaped as carbon dioxide from the waste package, it would flow through the rock. About 2 percent of the carbon-14 in commercial spent nuclear fuel is in a gas phase in the space (or gap) between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92). The atmospheric model used a gas-phase inventory of 0.122 curie of carbon-14 per waste package of commercial spent nuclear fuel at the time of emplacement. The atmospheric model estimated human health impacts for the population in the 80-kilometer (50-mile) region surrounding the repository.

In addition, DOE considered the possible impacts from the release of radon from the repository. Radon is a decay product of uranium and would be generated for as long as any uranium remained in the repository. Based on gas flow studies, DOE believes that radon would decay before it reached the ground surface. Appendix I, Section I.7.3, contains a more detailed screening discussion.

5.5.1 SOURCE TERM

The calculation of regional doses used an estimate of the annual release rate of carbon-14. The analysis based the carbon-14 release rate on the estimated time line of waste package container failures for the higher-temperature repository operating mode nominal scenario. If the same analysis were performed using waste package failures for the lower-temperature operating mode, the results would be nearly the same with slightly lower impacts. The expected number of commercial spent nuclear fuel waste package failures as a function of time was used to estimate the carbon-14 release rates after repository closure. The amount of material released from each package as a function of time was reduced to account for radioactive decay. As for the waterborne releases described in Section 5.4.1, credit was taken for the intact zirconium alloy cladding (on approximately 99 percent by volume of the spent nuclear fuel at emplacement) delaying the release of gas-phase carbon-14 (DIRS 153849-DOE 2001, p. 3-7). The remaining 1 percent by volume of the spent nuclear fuel either would have stainless-steel cladding (which degrades much more quickly than zirconium alloy) or would already have failed in the reactor. Thus, gas-phase releases from this fuel would have occurred before it was shipped to the repository. The maximum annual-release rate would occur about 1,700 years after repository closure, and the estimated maximum release rate would be 3.3 microcuries per year of carbon-14.

5.5.2 ATMOSPHERIC CONSEQUENCES TO THE LOCAL POPULATION

DOE used the *GENII* program (DIRS 100953-Napier et al. 1988, all) to model the atmospheric transport and human uptake of the released carbon-14 for the 80-kilometer (50-mile) population dose calculation.

Doses to the regional population around Yucca Mountain from carbon-14 releases were estimated using the population distribution shown in Chapter 3, Figure 3-25, which indicates that 76,000 people would live in the region surrounding Yucca Mountain in 2035. The computation also used current (1993 to 1996) annual average meteorology (see Appendix I, Table I-33). GENII calculated a dose factor of 4.6×10^{-9} person-rem per microcurie per year of release. For a 3.3-microcurie-per-year release, this corresponds to a maximum 80-kilometer annual population dose of 1.5×10^{-8} person-rem. This dose corresponds to 7.5×10^{-12} latent cancer fatality in the regional population of 76,000 persons during each year at the maximum carbon-14 release rate. This annual population radiological dose corresponds to a 70-year lifetime radiological population dose of 1.1×10^{-6} person-rem, which corresponds to 5.3×10^{-10} latent cancer fatality during the 70-year period of the maximum release.

5.5.3 ATMOSPHERIC CONSEQUENCES TO AN INDIVIDUAL

For a constant-sized population living only at the locations in the population distribution shown in Chapter 3, Figure 3-25, a maximally exposed individual for airborne releases would reside 24 kilometers (15 miles) south of the repository. The location for maximum dose is dependent on wind speed and wind direction, and is only considered for those locations where people currently reside (it was not a predetermined location). An individual radiological dose factor of 5.6×10^{-14} rem per microcurie per year of release was calculated using the GENII code for this location. For a 3.3-microcurie-per-year maximum release rate, the individual maximum radiological dose rate would be 1.8×10^{-13} rem per year, corresponding to a 9.2×10^{-17} probability of a latent cancer fatality. The 70-year lifetime dose would be 1.3×10^{-11} rem, representing a 6.4×10^{-15} probability of a latent cancer fatality.

5.6 Consequences from Chemically Toxic Materials

A number of nonradioactive materials that DOE would place in the repository will degrade over time into materials that are hazardous to human health at high concentrations in water. This section examines the consequences to individuals in the Amargosa Desert from releases of these nonradioactive materials.

Appendix I, Section I.3 discusses the inventory of chemically toxic materials that would be emplaced in the repository under the Proposed Action by element. Based on this inventory, a screening analysis (described in Appendix I, Section I.6.1) identified which of the chemically toxic materials could pose a potential risk to human health. Chromium, molybdenum, nickel, and vanadium were identified as posing such a potential risk, and these elements were further evaluated in a bounding consequence analysis, as described in Appendix I, Section I.6.2. This analysis makes the conservative assumption that all chromium dissolves in hexavalent form.

It should also be noted that all of the chromium, molybdenum, nickel, and vanadium considered are elements contained in the metals used to package the waste and support the packages. None of the materials inside the waste packages were considered because, except for about three packages, all packages would last for more than 50,000 years.

Table 5-14 summarizes the results of the bounding analysis. In some cases a Maximum Contaminant Level or Maximum Contaminant Level Goal was available for comparison to the calculated concentration. In other cases, only an Oral Reference Dose was available. The Oral Reference Dose can be compared to the intake that would result for a 70-kilogram (154-pound) person drinking 2 liters (0.53 gallon) of water per day.

The bounding consequence analysis estimated that the maximum peak concentration of chromium in groundwater used at exposure locations would be 0.01 milligram per liter. There are two measures for comparing human health effects for chromium. When the Environmental Protection Agency established its Maximum Contaminant Level Goals, it considered safe levels of contaminants in drinking water and

Table 5-14. Consequences from waterborne chemically toxic materials release during 10,000 years after repository closure estimated using a bounding calculation.

Material	Concentration in well water (milligram per liter)	Maximum Contaminant Level Goal[a] (milligram per liter)	Intake rate for a 70-kilogram person (milligram per kilogram per day)	Oral Reference Dose (milligram per kilogram per day)
Chromium (VI)	0.01	0.1	0.0004	0.005[b]
Molybdenum	0.009	NA[c]	0.0003	0.005[d]
Nickel	0.04	NA	0.001	0.02[e]
Vanadium	0.0002	NA	0.000006	0.007[f]

a. 40 CFR 141.51.
b. DIRS 148224-EPA (1999, all).
c. NA = not available.
d. DIRS 148228-EPA (1999, all).
e. DIRS 148229-EPA (1999, all).
f. DIRS 103705-EPA (1997, all).

the ability to achieve these levels with the best available technology. The Maximum Contaminant Level Goal for chromium is 0.1 milligram per liter (40 CFR 141.51). The bounding concentration is well below the Maximum Contaminant Level Goal for chromium (about one-tenth of this limit). The other measure for comparison is the reference dose factor for chromium, which is an intake of 0.0004 milligram of chromium per kilogram of body mass per day (DIRS 148224-EPA 1999, all). The reference dose factor represents a level of intake that has no adverse effect on humans. It can be converted to a threshold concentration level for drinking water. The conversion yields essentially the same concentration for the reference dose factor as the Maximum Contaminant Level Goal. At present, the bounding estimate of groundwater concentration of hexavalent chromium cannot be expressed in terms of human health effects (for example, latent cancer fatalities). The carcinogenicity of hexavalent chromium by the oral route of exposure has not been determined because of a lack of sufficient epidemiological or toxicological data (DIRS 148224-EPA 1999, all; DIRS 101825-EPA 1998, p. 48).

The estimated bounding concentration of molybdenum in groundwater used at exposure locations would be 0.009 milligram per liter. There is no Maximum Contaminant Level Goal for molybdenum but intake can be compared to the Oral Reference Dose. The intake rate from drinking 2 liters (0.53 gallon) per day of contaminated water by a 70-kilogram (154-pound) person would be 0.0003 milligram per kilogram per day. This is well below the Oral Reference Dose of 0.005 milligram per kilogram per day (DIRS 148228-EPA 1999, all).

The estimated bounding concentration of nickel in groundwater used at exposure locations would be 0.04 milligram per kilogram. There is no Maximum Contaminant Level Goal available for nickel but intake can be compared against the Oral Reference Dose. The intake rate from drinking 2 liters (0.53 gallon) per day of contaminated water by a 70-kilogram (154-pound) person would be 0.001 milligram per kilogram per day. This is well below the Oral Reference Dose of 0.02 milligram per kilogram per day.

The estimated bounding concentration of vanadium in groundwater used at exposure locations would be 0.0002 milligram per liter. There is no Maximum Contaminant Level Goal available for vanadium, but intake can be compared to the Oral Reference Dose. The intake rate from drinking 2 liters (0.53 gallon) per day of contaminated water by a 70-kilogram (154-pound) person would be 0.000006 milligram per kilogram per day. This is well below the Oral Reference Dose of 0.007 milligram per kilogram per day.

Because the estimated bounding concentrations of chromium, molybdenum, nickel and vanadium in well water would be below the Maximum Contaminant Level Goal or yield intakes well below the Oral Reference Dose, there is no further need to refine the calculation to account for physical processes that would limit mobilization of those materials or delay and dilute them during transport in the geosphere.

5.7 Consequences from Disruptive Events

The postclosure performance estimates discussed in Sections 5.4, 5.5, and 5.6 include the possible effects of changing climate and seismic events but do not address other events that could physically disturb the repository. In general, disruptive events have identifiable starting and ending times, in contrast to continuous processes such as corrosion. The disruptive events examined in this section are an *inadvertent intrusion* into the repository by a drilling crew and basaltic igneous (volcanic) activity.

5.7.1 HUMAN INTRUSION SCENARIO

DOE examined the consequences of a human intrusion scenario involving inadvertent drilling.

The human intrusion scenario analyzed in this EIS is consistent with the requirements of 40 CFR Part 197. The stylized human intrusion scenario is summarized as follows:

- The human intrusion would occur 30,000 years after permanent repository closure when there was enough degradation in waste packages that the driller might not detect the penetration.
- The intrusion would result in a single, nearly vertical borehole that penetrated a waste package and extended down to the saturated zone.
- Current practices for resource exploration would be used to establish properties (e.g., borehole diameter, drilling fluid composition).
- The borehole would not be adequately sealed and would permit infiltrating water and natural degradation processes to modify the borehole gradually.
- Only releases through the borehole to the saturated zone were considered; hazards to the drillers or to the public from material brought to the surface by the assumed intrusion were not included.

The human intrusion results were calculated probabilistically, analogous to the nominal scenario calculations for waterborne radioactive material releases. The calculations were carried out for the higher-temperature repository operating mode. For this stylized intrusion scenario, there would be no difference for the lower-temperature operating mode because exactly one waste package is intersected for both operating modes and its inventory is moved to the saturated zone where further transport does not depend on repository operating mode. Figure 5-6 shows the mean and 95th-percentile annual individual dose for 1 million years resulting from a human intrusion 30,000 years after repository closure for the set of 300 simulations. The values in Figure 5-6 represent the dose from a single waste package, and are not combined with releases for other waste packages that would fail due to other processes. The peak of the mean annual individual dose from human intrusion would be 0.002 millirem, occurring a short time after 100,000 years after repository closure. These results indicate that the repository would be sufficiently robust and resilient to limit releases caused by human intrusion to values well below the 15-millirem annual individual dose standard.

The analysis did not combine the results of the disruptive igneous event scenario with the results of the human intrusion scenario. However, combined results can be approximated by adding the results of the human intrusion analysis to that of the disruptive igneous event scenario, which would result in a total combined maximum dose. Based on the results presented in this section and Section 5.7.2, the highest mean annual individual dose that would result from an intrusion would be less than one-tenth of the radiological dose from a disruptive igneous event.

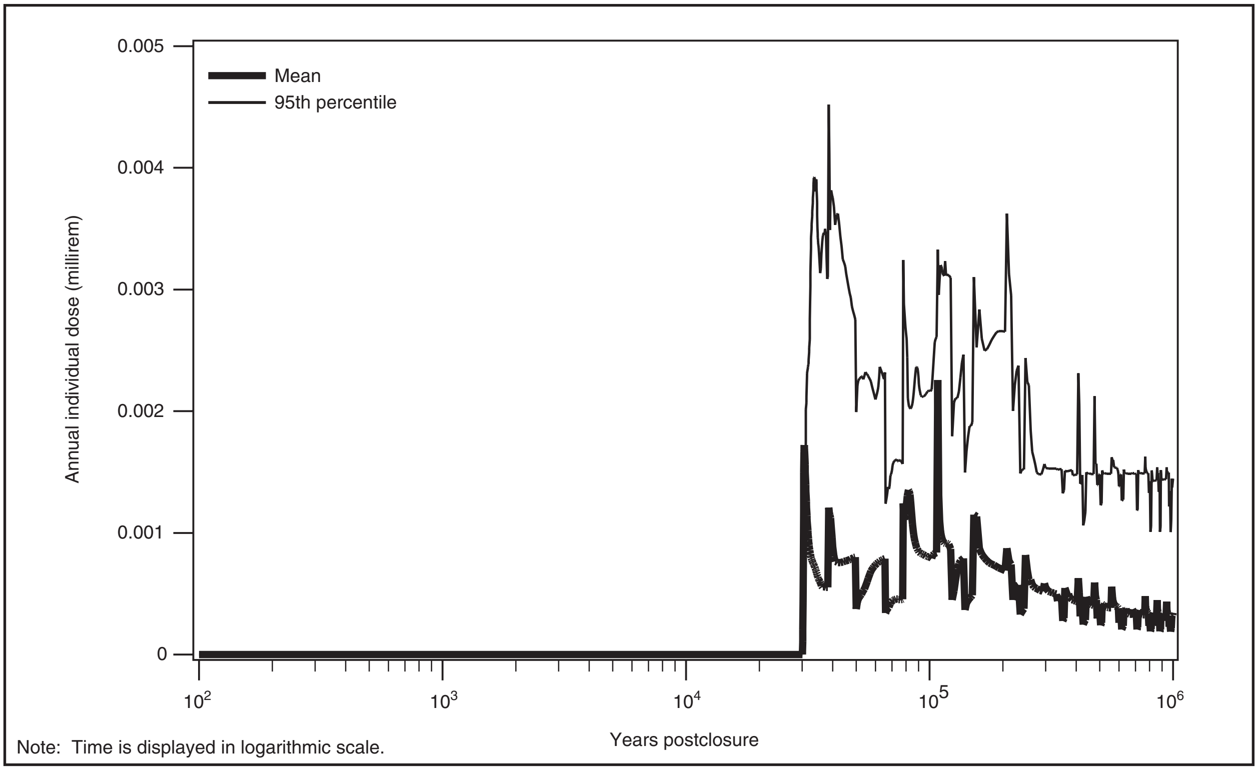

Figure 5-6. Mean and 95th-percentile annual individual dose at the RMEI location resulting from human intrusion 30,000 years after repository closure under the higher-temperature repository operating mode.

A sensitivity study where the human intrusion occurs at 100 years after repository closure has also been conducted (DIRS 157307-BSC 2001, Enclosure 1).

5.7.2 IGNEOUS ACTIVITY SCENARIO

The analysis of igneous activity utilized a model for volcanic eruptions that would intersect drifts and bring waste to the surface, and a model for igneous intrusions that would damage waste packages, thereby exposing radionuclides to groundwater for transport.

5.7.2.1 Volcanic Eruption Events

The conceptualization of a volcanic eruption at Yucca Mountain envisioned an igneous dike that would rise through the Earth's crust and intersect one or more repository drifts. An eruptive conduit could form somewhere along the dike as it neared the land surface, feeding a volcano at the surface. Waste packages in the direct path of the conduit would be destroyed, and the waste in those packages would subsequently be entrained in the eruption. Volcanic ash would be contaminated, erupted, and transported by wind. Ash would settle out of the plume as it was transported downwind, resulting in an ash layer on the land surface. Members of the public would then receive a radiation dose from exposure pathways associated with the contaminated ash layer.

Model development included the selection of conservative assumptions about the event, selection of input parameter distributions characterizing important physical properties of the system, and use of a computational model to calculate entrainment of waste in the erupting ash. Each intrusive event (a swarm of one or more dikes) was assumed to generate one or more volcanoes somewhere along its length, but eruptions would not need to occur within the repository footprint. Approximately 77 percent of intrusive events that intersected the repository would be associated with one or more surface eruptions within the repository footprint. The number of eruptive conduits (volcanoes) is independent of the number of dikes in a swarm. Characteristics of the eruption such as eruptive power, style (violent versus normal), velocity, duration, column height, and total volume of erupted material, are included in the analysis.

5.7.2.2 Groundwater Transport of Radionuclides Following Igneous Intrusion Event

The conceptualization of radionuclide release and transport away from waste packages damaged by an igneous intrusion that intersected the repository is similar to the nominal model for radionuclide release and transport (discussed in Section 5.4), but was modified to include the intrusion. The igneous intrusion groundwater transport model includes a set of input parameters to define a modified source term for use in the nominal scenario flow and transport model. There are three main components to the model: the behavior of the waste packages and other engineered barrier system elements damaged because of their proximity to an igneous intrusion; groundwater flow and radionuclide transport away from the waste packages; and calculation of the number of waste packages damaged as a result of the igneous intrusion.

The analysis assumed that waste packages close to the point of intrusion would be so damaged that they would provide no further protection for the waste. Actual conditions would be uncertain, and damage probably would range from moderate to extensive. Nominal models for radionuclide mobilization and transport were used even though conditions would change in the drift following intrusion. All waste in the most severely damaged packages would be immediately available for transport in the unsaturated zone, depending on solubility limits and the availability of water, which was determined using the seepage model for nominal performance. The thermal, chemical, and mechanical effects of the intrusion on the drift environment were neglected. No credit was taken for water diversion by the remnants of the drip shield or waste package, and cladding was assumed to be fully degraded. Actual thermal, chemical, hydrological, and mechanical conditions in the drift following igneous intrusion are unknown, although conservatively assuming that the engineered barriers would have completely failed is sufficient to compensate for the uncertainty associated with conditions in the drift.

5.7.2.3 Results for Igneous Activity Scenario

The approach taken to calculate doses resulting from the igneous activity scenario is consistent with the probabilistic methodology described in Nuclear Regulatory Commission guidance (DIRS 103760-NRC 1998, all; DIRS 119693-Reamer 1999; all). Scenario consequences are multiplied ("weighted") by the probability of occurrence of the scenario to yield an appropriate estimate of the overall risk posed by low-probability events. The probability of igneous activity is extremely low (the mean annual probability is 1.6×10^{-8}), and the probability of more than one igneous disruption occurring during the next 100,000 years is far below the level of concern. Therefore, the analysis considered only a single igneous eruption within the repository during the next 100,000 years, occurring with a mean 100,000-year probability of 1.6×10^{-3}. The year in which that eruption could occur is uncertain; therefore, the igneous eruption scenario was evaluated as if it were many different eruptive scenarios, each occurring in a different 25-year time interval, and each occurring with a probability 25 times that of the annual probability. The average dose resulting from igneous disruption was determined by calculating doses resulting from igneous events in each 25-year period, multiplying by the probability (mean 25-year probability of 4.0×10^{-7}), and adding the doses from each *disruptive event*. For computational efficiency, igneous intrusions that would not result in a surface eruption were simulated using a simpler approach in which the time of intrusion was sampled randomly from the 100,000-year period, and the probability associated with each simulation is the full 100,000-year probability of 1.6×10^{-3}. Probability-weighted doses from both eruptive and intrusive events were added together to give the total dose from igneous disruption.

The average doses from igneous activity calculated in this manner incorporate uncertainties regarding the time at which the igneous event could occur, and account for the reality that, as time passed, the likelihood would increase that igneous disruptions could have already occurred. For example, a person living downwind from Yucca Mountain 10,000 years after repository closure would have a mean probability of 1.6×10^{-4} of receiving a radiation dose from soil contaminated by an igneous event sometime in the past. The probability-weighted average dose emphasizes the overall risk to a person living downwind from Yucca Mountain, in terms of both the likelihood and consequences of the igneous activity scenario.

Figure 5-7 shows the mean probability-weighted dose histories representing possible doses to an individual for the higher-temperature repository operating mode. The figure also shows the nominal scenario for comparison. The igneous activity scenario is only simulated to 100,000 years because the nominal scenario impacts dominate after that time. These summary curves are based on 5,000 individual dose histories calculated using different sets of uncertain input parameters in the model. For approximately the first 20,000 years, the dose history is a smooth curve that is dominated by the effects of volcanic eruption. The probability-weighted mean annual individual dose during this period would reach a peak of approximately 0.1 millirem about 300 years after repository closure, and then decline because of radioactive decay of the relatively shorter-lived radionuclides that contributed to doses from the ash fall exposure pathway. The major contributors to the eruptive dose would be americium-241, plutonium-238, plutonium-239, and plutonium-240. Strontium-90 would be a significant contributor at extremely early times, but would drop off rapidly because of radioactive decay (*half-life* of 29.1 years). Inhalation of resuspended particles in the ash layer would be the primary exposure pathway during this period, and the smooth decline of the mean dose curve from approximately 300 to 2,000 years would result from decay of americium-241 (half-life of 432 years). From approximately 20,000 years after closure, the mean igneous dose would be dominated by groundwater releases from packages damaged by igneous intrusions that did not erupt to the surface. The irregular shape of the curve from this point forward is in part a result of the groundwater transport processes, and in part reflects the occurrence of intrusive events at random times, rather than the prescribed intervals used for extrusive simulations. The intrusive event could occur at any time, and the first appearance of groundwater doses in the mean curve at approximately 20,000 years reflects retardation during transport, rather than the absence of intrusions at earlier times. Results for the lower-temperature operating mode would be essentially identical to those for the higher-temperature mode because the probability of an igneous intrusion interacting with waste packages is reduced for the wider waste package spacing. However, the overall probability of an igneous intrusion intersecting the potential repository would increase because of a larger repository emplacement area.

The dose history for the igneous activity scenario in Figure 5-7 is presented as a probability-weighted annual dose resulting from events occurring at uncertain times throughout the period of simulation. This approach to calculating and displaying the probability-weighted annual doses is consistent with the approach specified by 40 CFR Part 197 and is required for determination of the overall expected annual dose. However, displays of the probability-weighted annual dose do not allow direct interpretation of the conditional annual dose, which is the annual dose an individual would receive if a volcanic event occurred at a specified time. For conditional analyses, the probability of the event is set equal to one, and the time of the event is specified. Conditional results do not provide a meaningful estimate of the overall risk associated with igneous activity at Yucca Mountain, but they provide insights into the magnitude of possible consequences for specific sets of assumptions. A sensitivity calculation was performed to provide results for this conditional case (DIRS 154659-BSC 2001, pp. 3-47 to 3-48). Conditional mean annual dose histories were calculated for eruptive events at 100, 500, 1,000, and 5,000 years. The conditional mean dose in the first year after an eruptive event at 100 years after repository closure is approximately 13 rem. The conditional dose in the first year after an eruption decreases to approximately one-half this level for an eruption 500 years after closure, and is approximately 10 percent of this value for an eruption 5,000 years after closure. This calculation was made with a previous TSPA model (DIRS 153246-CRWMS M&O 2000, all) that has some differences from the model used elsewhere in this EIS for long-term performance (DIRS 157307-BSC 2001, Enclosure 1). The differences that affect the analysis described above are that dose factors were revised to conform to 40 CFR Part 197 and the

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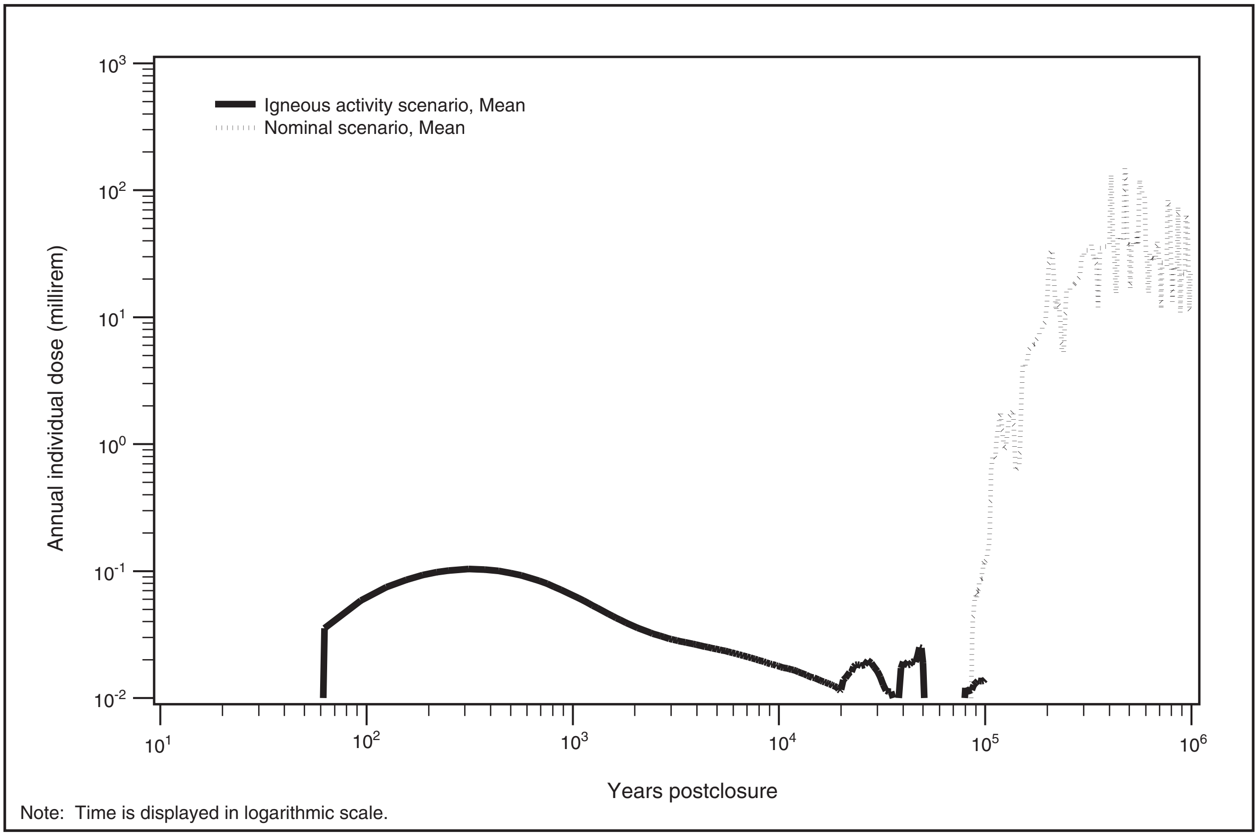

Figure 5-7. Mean (based on 5,000 simulations of total system performance, each using random samples of uncertain parameters) annual individual dose at the RMEI location resulting from igneous disruptions under the higher-temperature repository operating mode, with the mean dose history at this location for the higher-temperature operating mode nominal scenario.

distance analyzed is 20 kilometers rather than 18 kilometers from the repository. These changes would be expected to increase the dose values at 100 years and 500 years by a factor of between 2 and 3. The results at the later times would increase by about 20 percent.

5.8 Nuclear Criticality

This section examines the probability of isolated nuclear criticality events in waste packages and in surrounding rock. A short tutorial on the physics of nuclear criticality and the associated conditions that can cause such an event is provided in the Science and Engineering Report (DIRS 153849-DOE 2001, pp. 4-406 to 4-409). The tutorial provided in the Science and Engineering Report identifies the required conditions for nuclear criticality at the proposed repository. One of the required conditions for nuclear criticality is the presence of a moderator such as liquid water. Liquid water could only be introduced into the waste package if the waste package failed. The following information is excerpted from the Yucca Mountain Science and Engineering Report (DIRS 153849-DOE 2001, pp. 4-412 to 4-416).

5.8.1 PROBABILITY OF INTERNAL CRITICALITY FOR COMMERCIAL SPENT NUCLEAR FUEL

Actually, there is a very low probability that any liquid water would enter a specific package; thus, the probability estimated here is very conservative. Each package would contain a neutron absorber that would have the important function of capturing neutrons and helping to prevent a criticality. The conditions of waste package failure and entrance of liquid water are required for internal criticality. The probability of these conditions occurring would be very small. The probability of the loss of neutron absorber would increase with time after 10,000 years. As the internal components of a waste package degraded, the assemblies in the package would collapses reducing the spacing between the fuel rods. This would reduce the probability of criticality because of the reduced volume between fuel rods available for the moderator to fill. Another factor tending to reduce the probability of criticality with time would be the eventual breach of the bottom of the waste package, which would drain most of the water in the waste package that acted as a moderator. The potential for criticality of commercial spent nuclear fuel would be maximized when the internal basket was fully degraded, but with the assemblies remaining intact and no breach of the bottom of the waste package. Under these circumstances, the calculated probability of a critical event within the total inventory of the 21-PWR Absorber Plate waste packages would be less than 2×10^{-7} in 10,000 years (after closure of the repository). The 21-PWR Absorber Plate waste package was chosen for criticality calculations because it is the design for fuel with the highest reactivity and thus would be expected to have the highest probability of criticality.

5.8.2 PROBABILITY OF INTERNAL CRITICALITY FOR CODISPOSED DOE SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

Actually, there is a very low probability that any liquid water would enter a specific package; thus, the probability estimated here is very conservative. Evaluations have been performed of the criticality potential of waste packages that would contain high-level radioactive waste glass and certain types of codisposed DOE spent nuclear fuel. The probability of criticality for these fuel types would generally be less than the small value of 2×10^{-7} for commercial spent nuclear fuel. The primary reasons are the lower fissile loading per waste package and the greater flexibility to install neutron absorber due to smaller fuel mass per waste package.

5.8.3 PROBABILITY OF CRITICALITY FOR THE IMMOBILIZED PLUTONIUM WASTE FORM

Actually, there is a very low probability that any liquid water would enter a specific package; thus, the probability estimated here is very conservative. The design of the immobilized plutonium waste form makes criticality virtually impossible. The degradation rate of the ceramic waste form would be so slow that, in the unlikely event that the waste package was breached and filled by a continuous dripping of water, it would be nearly 50,000 years after emplacement before enough of this waste form had degraded to permit any significant separation of the uranium and plutonium from the gadolinium and hafnium neutron absorbers. Even after degradation of the waste form, the gadolinium and hafnium are generally less soluble than the fissile material, so they would not be transported out of the waste package while the fissile material remains. Even if extremely unlikely chemistry conditions occurred that would make the gadolinium sufficiently soluble to be removed before the fissile material, enough of the completely insoluble hafnium would remain to prevent criticality.

5.8.4 PROBABILITY OF EXTERNAL CRITICALITY

Calculation of the probability of external criticality starts with the assumption that the waste package fails and liquid water has entered the waste package. Actually, there is a very low probability that any liquid water would enter a specific package; thus, the probability estimated here is very conservative. The probability of an external criticality event in either the repository or the rock beneath it is less than 4×10^{-12} in 10,000 years following repository closure. This low probability is primarily a result of the following Yucca Mountain characteristics: (1) limited dripping water to transport enough fissile material out of the waste package and into a geometry favorable for criticality; (2) a limited number of regions in the rock below the drifts to allow for fissile material accumulation in a geometry favorable for criticality; (3) a low concentration of fissile material in the water exiting out of a breached waste package due to low waste form solubility; and (4) lack of a chemical means to accumulate fissile materials and lack of a reducing environment to encourage precipitation.

5.8.5 EFFECT OF A STEADY-STATE CRITICALITY ON RADIONUCLIDE INVENTORY

If a steady-state criticality was to occur, it would be very unlikely to have a power level greater than 5 kilowatts. The power level would be limited because higher power, and thus higher temperatures, would evaporate the water that served as a moderator. An extremely conservative assumption would be that the criticality could endure for 10,000 years, which is the average period of a climate cycle that might have a high enough rainfall or drip rate to sustain the required level of water moderation against evaporation. For a typical commercial spent nuclear fuel waste package, a steady-state criticality would result in an increase of the inventory of certain radionuclides in that waste package. For the very conservative duration of 10,000 years, this increase would be less than 30 percent for the radionuclides in that package. The incremental impact of steady-state criticality events on the total inventory for the repository has been evaluated and is expected to be insignificant.

5.8.6 TRANSIENT CRITICALITY CONSEQUENCES

In the unlikely event that a transient criticality were to occur, a rapid initiating event could produce a peak power level of up to 10 megawatts for less than 60 seconds. After this brief period, rapid boiling of the water moderator would shut down the criticality. The short duration would limit the increase in radionuclide inventory to a factor of 100,000 smaller than that generated by the 10,000-year steady-state criticality. Other consequences of a transient criticality would be a peak temperature of 233ºC (451ºF) and a peak overpressure of 20 atmospheres. Both conditions would last 10 seconds or less and would not be expected to cause enough damage to the waste package or change its environment enough to have a significant impact on repository performance.

5.8.7 AUTOCATALYTIC CRITICALITY

When a criticality begins, there are several mechanisms that tend to shut it down. For example, the rapid evolution of heat and pressure can expand the fissile material, reducing its density and destroying the critical mass configuration. Evolution of steam can remove water moderator or decrease its effective density. In the case of autocatalytic criticality, there is such a high concentration of fissile material that there is an excess of critical mass and high rates of fission are achieved before any of the shutdown mechanisms occur. The result can be a “runaway” chain reaction, usually resulting in a steam explosion, or in the case of a nuclear bomb, a nuclear explosion. Contrary to popular belief, achieving such a configuration is extremely difficult and requires some very deliberate engineering. An autocatalytic criticality is not credible for the potential repository. Autocatalytic criticality is not possible at all for low-enriched waste forms, nor is it possible for the waste form inside the waste package. Even for highly enriched waste forms, or those containing nearly pure plutonium-239, achieving a critical mass outside a waste package would require the entire fissile content of the waste package to be spread uniformly in a nearly spherical shape, or it would require the extremely unlikely commingling of large amounts of transported fissile material from at least two waste packages containing highly enriched waste forms. Because the igneous rock at Yucca Mountain is unlikely to contain deposits that can efficiently accumulate fissile material, the probability of creating such a critical mass from a single or multiple waste packages containing highly enriched waste forms is so low as to be not credible.

5.8.8 DISRUPTIVE NATURAL EVENTS INFLUENCING CRITICALITY

The potential impact of disruptive natural events, such as seismic activity or igneous intrusion, on the risk of criticality in the repository has been studied. Seismic events could produce a rapid change in the configurations of waste forms and waste packages, potentially creating a critical configuration.

The potential adverse criticality considerations of igneous intrusion into the repository include: (1) the possibility of immediate waste package breach, (2) the separation of a significant fraction of the fissile material from the neutron absorber by magma transport, and (3) the accumulation of a critical mass of fissile material from, or within, the transporting magma. The potential for criticality following igneous intrusion has been evaluated for commercial spent nuclear fuel under extremely conservative assumptions, and no sufficiently probable mechanism for accumulating a critical mass has been identified.

5.9 Consequences to Biological Resources and Soils

DOE has considered whether the proposed repository would affect biological resources in the Yucca Mountain vicinity after closure through heating of the ground surface and through radiation exposure as the result of waste migration through groundwater to discharge points. No additional analyses for biological resources and soil have been performed for the design and operating mode changes made after the Draft EIS was published. The temperatures for the higher-temperature operating mode now being considered are bounded by the temperatures analyzed for the high-thermal load scenario in the Draft EIS and presented in this section.

After closure, heat from the radioactive decay of the waste could cause temperatures in the rock near the waste packages to rise above the boiling point of water at this altitude [96°C (205°F)] (DIRS 101779-DOE 1998, Volume 3, p. 3-36). The period the subsurface temperature could remain above the boiling point would vary from a few hundred years to a few thousand years, depending on the operating mode. Conduction and the flow of heated air and water through the rock (advection) would carry the heat from the waste packages through the rock to the surface and to the aquifer.

Although the atmosphere would remove excess heat when it reached the ground surface, the temperature of near-surface soils probably would increase slightly. Predicted increases in surface soil temperatures range from approximately 10°C (18°F) at the bedrock-soil interface (DIRS 100627-Bodvarsson and Bandurraga 1996, p. 510) to 6°C (10.8°F) for dry soil at a depth of 2 meters (6.6 feet) (Table 5-15). To address soil heterogeneity (differences in depth and water content), a recent study (DIRS 103618-CRWMS M&O 1999, all) modeled soil temperature increases at various depths under wet (saturated) and dry (no water at all) soil conditions for the high thermal load. They predicted that temperatures of near-surface soils would be unlikely to rise more than a few degrees (Table 5-14) but would increase with depth from the surface. Surface soil temperatures would start to increase approximately 200 years after repository closure and would peak more than 1,000 years after repository closure. Later, the temperature would gradually decline and would approximate prerepository conditions after 10,000 years (DIRS 103618-CRWMS M&O 1999, Figure 30 and p. 41).

Table 5-15. Predicted temperature changes of near-surface soils under the high thermal load scenario.[a,b]

Soil depth (meters)[c]	Predicted temperature increase [a]	
	Dry soil	Wet soil
0.5	1.5°C (2.7°F)	0.2°C (0.36°F)
1.0	3.0°C (5.4°F)	0.4°C (0.72°F)
2.0	6.0°C (10.8°F)	0.8°C (1.4°F)

a. Source: DIRS 103618-CRWMS M&O (1999, p. 38).
b. The high thermal load scenario was described and analyzed in the Draft EIS; this is not to be confused with the higher-temperature operating mode discussed in this Final EIS, which has a lower design heat loading.
c. To convert meters to inches, multiply by 39.37.

The maximum change in temperature would occur directly above the repository, affecting approximately 5 square kilometers (1,250 acres) under the higher-temperature operating mode. The effects of repository heat on the surface soil temperatures would gradually decline with distance from the repository (DIRS 103618-CRWMS M&O 1999, p. 43). Although not modeled, the increase in surface soil temperature would be lower under the lower-temperature operating mode, and the area that could be affected would be larger [as much as 6.2 square kilometers (1,550 acres) above the repository for the lower-temperature operating mode].

There is considerable uncertainty in the estimates of soil temperature increases due to uncertainties in the thermal properties of the soil at Yucca Mountain, particularly thermal conductivity (the amount of heat that can be conducted through a unit of soil per unit time) (DIRS 103618-CRWMS M&O 1999, p. 50). The predicted temperature increase for dry soil provides a conservative estimate of the temperature increase that could occur because even partially saturated soil has a much greater thermal conductivity than dry soil. Soil moisture content recorded at a depth of 15 centimeters (6 inches) was as low as 3 percent on some study sites during some months, but the soil was never completely dry (DIRS 105031-CRWMS M&O 1999, p. 14).

A depth of 1 meter (3.3 feet) is within the root zone for many desert shrubs. A temperature increase of 3°C (5.4°F) could affect root growth and other soil parameters such as the growth of microbes or nutrient availability. Studies at Yucca Mountain (DIRS 105031-CRWMS M&O 1999, pp. 11 to 46) show that due to natural variations some plant species experienced a spatial range in soil temperatures of 4°C (7.2°F) at a depth of 0.45 meter (18 inches), which is comparable to the 0.5-meter (20-inch) depth used by DIRS 103618-CRWMS M&O (1999, pp. 37-41). Impacts to biological resources probably would consist of an increase of heat-tolerant species over the repository and a decrease of less tolerant species. In general, areas affected by repository heating could experience a loss of shrub species and an increase in annual species. A gradual (over 1,000 years) temperature increase of the magnitude predicted (DIRS 103618-CRWMS M&O 1999, all) probably would have less effect on the plant community than a more rapid change.

The predicted increase in temperature would extend as far as 500 meters (1,600 feet) beyond the edge of the repository, with the greatest increase in temperature occurring in soils directly above the repository. A shift in the plant species composition, if any, would be limited to the area within 500 meters of the repository footprint [that is, as much as 8 square kilometers (2,000 acres)].

A shift in the plant community probably would lead to localized changes in the animal community that depends on it for food and shelter. Specific plant and animal species and community changes cannot be predicted with certainty because changes in climate or seasonal episodic events (droughts, high rainfall) can substantially change species responses to single factors. However, the variation in surface soil temperatures at Yucca Mountain that are caused by elevation, slope, aspect, and other natural attributes suggest that soil temperature increases of the magnitude predicted (DIRS 103618-CRWMS M&O 1999, pp. 44 to 48) are probably within the adaptive range of some plant species now at Yucca Mountain (DIRS 105031-CWRMS M&O 1999, pp. 11 to 46).

Some reptiles, including the desert tortoise, exhibit temperature-dependent sex determination (DIRS 103463-Spotila et al. 1994, all). Nest temperatures have a direct effect on sex determination, with low temperatures resulting in predominately male hatchlings and high temperatures resulting in predominately females. Although existing experimental data do not adequately represent the large fluctuations in nest temperatures in natural settings, an increase in soil temperature due to repository operations could influence the sex ratio and other aspects of the life history of the desert tortoise population residing over the repository footprint. However, depth to the top eggs of 23 nests at Yucca Mountain during 1994 averaged 11 centimeters (4.3 inches). Predicted temperature increases of clutches at that depth based on modeling results (DIRS 103618-CRWMS M&O 1999, pp. 37 to 42) would be less than 0.5ºC (0.9°F). Given the ranges of critical temperatures reported by DIRS 103463-Spotila et al. (1994, all), an increase of this magnitude would be unlikely to cause adverse effects.

Changes in plant nutrient uptake, growth, and species composition, as a result of increases in soil temperature over long periods of time, could influence vegetation community dynamics and possibly alter desert tortoise habitat structure in areas immediately above the repository. However, little is known about the effects that minor alterations in habitat would have on desert tortoise population dynamics.

As discussed in Sections 5.4 and 5.6, in the distant future water at certain discharge points would be likely to carry concentrations of radionuclides and chemically toxic substances. DOE did not quantify impacts to biological resources from irrigation water extracted at the RMEI location, from irrigation water extracted at 30 kilometers (19 miles) downgradient from the potential repository, or for the evaporation of water at Franklin Lake Playa (where there is no surface water at present). The estimated doses to humans exposed to this water would be very small. Expected dose rates to plants and animals would be much less than 100 millirad per day. The International Atomic Energy Agency concluded that chronic dose rates less than 100 millirad per day are unlikely to cause measurable detrimental effects in populations of the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992, p. 53).

The desert tortoise is the only threatened or endangered species in the analyzed repository land withdrawal area (DIRS 104593-CRWMS M&O 1999, p. 3-14). Desert tortoises are rare or absent on or around playas (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411; DIRS 103160-Bury and Germano 1994, pp. 64 and 65); therefore, DOE anticipates no impacts to this species from contaminated water resources at Franklin Lake Playa in the future.

Impacts to surface soils would be possible. Changes in the plant community as a result of the presence of the repository could lead to an increase in the amount of rainfall runoff and, therefore, an increase in the erosion of surface soils, thereby increasing the sediment load in ephemeral surface water in the immediate Yucca Mountain vicinity.

5.10 Summary

Potential long-term impacts to human health from a repository at Yucca Mountain would be dominated by impacts from radioactive materials in the waterborne pathway under the Proposed Action. Although future disruptive events (human intrusion, volcanic activity, seismic activity) would change radiation exposure rates, the effect of these on the reported impacts for the nominal scenario would be small.

Tables 5-6 and 5-10 list individual doses from groundwater releases of radionuclides during 10,000 years after repository closure. The mean annual individual doses at the RMEI location are summarized in Table 5-16. The mean annual individual doses in Table 5-16 are much less than the limit of 15 millirem in 40 CFR Part 197.

Table 5-16. Individual impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the Proposed Action.[a]

Operating mode	Peak mean annual individual dose at the RMEI location (millirem)[b]	Peak mean annual probability of an LCF[c]
Higher-temperature	0.00002	6×10^{-10}
Lower-temperature	0.00001	4×10^{-10}

a. Values based on the mean peak-dose rates from 300 simulations of total system performance using random samples of uncertain parameters.
b. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the potential repository.
c. LCF = latent cancer fatality.

Tables 5-7 and 5-11 list estimated lifetime and 10,000-year integrated radiation dose impacts for members of the affected population from the groundwater release pathway during the first 10,000 years after repository closure. Table 5-17 summarizes the health effects for the affected population of 74,000 persons based on a 10,000-year integrated basis.

The average mortality rate for cancer deaths per 100,000 persons in Nevada is 202 (DIRS 153066-Murphy 2000, p. 83). Using the Nevada cancer death rate, about 154 cancer fatalities would normally occur each year in the population affected by groundwater potentially contaminated by a repository at Yucca Mountain (74,000 persons). All of the values in Table 5-17 are much smaller than 1, meaning that it is most likely than no person would die due to groundwater contamination by radiological material in the 10,000-year period after repository closure. This comparison clearly indicates that human health impacts associated with effects on groundwater from the Proposed Action would be very small for the affected population. Using the Nevada cancer death rate, about 140 cancer fatalities would normally occur each year in the population within an 80-kilometer radius of Yucca Mountain (assuming a population of about 76,000 persons). All of the values in Table 5-17 are much smaller than 1.0, meaning that it is most likely that no person would die due to groundwater contamination by radiological material in the 10,000-year period after repository closure. This comparison clearly indicates that human health impacts associated with the Proposed Action would be very small for the population in general.

Table 5-17. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the Proposed Action.[a]

Operating mode	Peak annual LCFs[b]	10,000-year integrated LCFs
Higher-temperature	0.000003	0.0002
Lower-temperature	0.000002	0.0002

a. Values based on the mean peak-dose rates from 300 simulations of total system performance using random samples of uncertain parameters.

b. LCFs = latent cancer fatalities.

The analysis indicates (as listed in Table 5-17 and the peak dose values) that there is no significant difference in impacts due to the operating mode, even though the impacts for the higher-temperature mode appear to be slightly larger than those impacts for the lower-temperature mode. One reason for the similarity in annual individual dose between the operating modes is that most waste packages would still be intact beyond the time at which the repository temperature would be elevated much above ambient rock temperatures (DIRS 155950-BSC 2001, p. 7-85). Thus, most radionuclides would not be released until long after the thermal effects had subsided and, therefore, the operating modes would not have a large effect on the peak doses.

The EPA has set annual dose limits of 15 millirem to an individual for human intrusion and igneous disruption events (40 CFR Part 197). As shown in Figure 5-7, the peak of the mean annual dose rate from a human intrusion 30,000 years after repository closure would be 0.002 millirem. The probability weighted mean annual dose to an individual for the igneous intrusion scenario would have a peak of 0.1 millirem. Both of these results are well below the regulatory limits.

The peak mean annual individual doses at the RMEI location in the first 1 million years after repository closure would be 150 millirem for the higher-temperature operating mode and 120 millirem for the lower-temperature operating mode. These doses do not specifically include the effects of disruptive events. The effects of disruptive events would be very small compared to the 1-million-year peak annual dose. These effects are evaluated separately and reported in Section 5.7.

As listed in Table 5-14, human impacts from chemically toxic materials would be unlikely because water concentrations would be below Maximum Contaminant Level Goals (40 CFR 191.51) or Oral Reference Doses (chromium, DIRS 148224-EPA 1999, all; molybdenum, DIRS 148228-EPA 1999, all; nickel, DIRS 148229-EPA 1999, all; and vanadium, DIRS 103705-EPA 1997, all). Estimated concentrations of radionuclides in groundwater (see Table 5-9) would be hundreds of thousands of times less than regulatory limits (40 CFR 197.30). Atmospheric release of carbon-14 would yield an estimated 80-kilometer (50-mile) population impact of 5.3×10^{-10} latent cancer fatality during the 70-year period of maximum release, much lower than the groundwater-borne population impacts. Finally, as discussed in Section 5.9, there are no anticipated adverse impacts to biological resources from either repository heating effects or the migration of radioactive materials.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

104328	ASTM 1998	ASTM (American Society for Testing and Materials). 1998. *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip.* B 575-97. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 241816.
100627	Bodvarsson and Bandurraga 1996	Bodvarsson, G.S. and Bandurraga, T.M., eds. 1996. *Development and Calibration of the Three-Dimensional Site-Scale Unsaturated Zone Model of Yucca Mountain, Nevada.* Berkeley, California: Lawrence Berkeley National Laboratory. ACC: MOL.19970211.0176.
152059	BSC 2001	BSC (Bechtel SAIC Company) 2001. *Performance Assessment of U.S. Department of Energy Spent Fuels in Support of Site Recommendation.* CAL-WIS-PA-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010627.0026.
154554	BSC 2001	BSC (Bechtel SAIC Company) 2001. *Lower-Temperature Subsurface Layout and Ventilation Concepts.* ANL-WER-MD-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010718.0225.
154659	BSC 2001	BSC (Bechtel SAIC Company) 2001. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.
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6

Environmental Impacts of Transportation

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6. ENVIRONMENTAL IMPACTS OF TRANSPORTATION

This chapter describes the potential environmental consequences of transporting the spent nuclear fuel and high-level radioactive waste described in Chapter 2 and Appendix A from 72 commercial and 5 U.S. Department of Energy (DOE, or the Department) sites to the Yucca Mountain site under the Proposed Action. This chapter also separately describes the potential impacts of transportation activities in the State of Nevada.

On a national basis DOE analyzed impacts of transporting spent nuclear fuel, including potential commercial spent mixed-oxide fuel containing surplus plutonium that originated from U.S. defense programs, and high-level radioactive waste, including high-level radioactive waste that could contain immobilized surplus plutonium from U.S. defense programs. These impacts include all activities necessary to transport these materials, from loading at the commercial and DOE facilities to delivery at the Yucca Mountain site. In addition, although DOE would prefer that most shipments be carried out by rail, the analysis addressed two scenarios—*mostly legal-weight truck* and *mostly rail*. These two scenarios allowed the analysis to encompass the range of potential impacts for any mix of truck and rail shipments that would actually occur. Because naval spent nuclear fuel would not be shipped by legal-weight truck (DIRS 101941-USN 1996, all) and not all of the generator sites can handle rail casks, the national scenarios involve the use of mostly legal-weight truck shipments (with only naval spent nuclear fuel being transported by rail) or mostly rail shipments (with transportation of some commercial spent nuclear fuel by truck). In addition, as part of the mostly rail scenario, the analysis assessed impacts of short hauls of commercial spent nuclear fuel in heavy-haul trucks or barges from some commercial sites to nearby railheads.

For the discussion of potential impacts of transportation by truck or rail in Nevada, such impacts would be a subset of the impacts of potential national impacts. They are discussed separately so they can be compared to a third mode of transportation, the use of heavy-haul trucks, for spent nuclear fuel and high-level radioactive waste that would arrive in Nevada by rail. Thus, the analysis considered three alternative modes of transportation for shipments once they would arrive in Nevada: (1) for those arriving by legal-weight truck, continuing the shipments by legal-weight truck to the Yucca Mountain site; (2) for those arriving by train, continuing the shipments by rail using a branch rail line in one of five candidate rail corridors to the site; or (3) for those arriving by rail, unloading the shipments from railcars and loading them on heavy-haul trucks at an intermodal transfer station for shipment to the site on one of five candidate highway routes. Figure 6-1 shows these three options. The candidate highway routes for heavy-haul trucks and rail corridors for a potential branch rail line are called *implementing alternatives*. Figure 6-2 shows the transportation implementing alternatives and their relationships to the national and Nevada transportation scenarios and to the mix of rail and legal-weight truck transportation modes that make up each scenario.

Section 6.1 summarizes both national and Nevada transportation activities. Chapter 2, Section 2.1.3, also describes national and Nevada transportation activities. Section 6.2 assesses the potential impacts of national transportation from the 77 sites to Yucca Mountain. Section 6.3 assesses potential impacts from transportation activities in Nevada. Chapter 2 describes the receipt and unloading of shipping casks at the repository (Section 2.1.2.1.1.1), the preparation of empty casks for reshipment (Section 2.1.2.1.1.3), and the potential construction and operation of a cask maintenance facility (Section 2.1.3.4). Chapter 4, Section 4.1.15, evaluates potential environmental impacts from the offsite manufacturing of shipping casks for commercial spent nuclear fuel and DOE spent nuclear fuel and high-level radioactive waste. Chapter 8, Section 8.4, discusses cumulative impacts of transportation for the Proposed Action and anticipated future radioactive material transportation activities. Appendix J contains details on transportation analysis methods and results. Appendix M provides information that is not needed to evaluate environmental impacts but that could be useful to readers to gain an understanding of nuclear waste transportation.

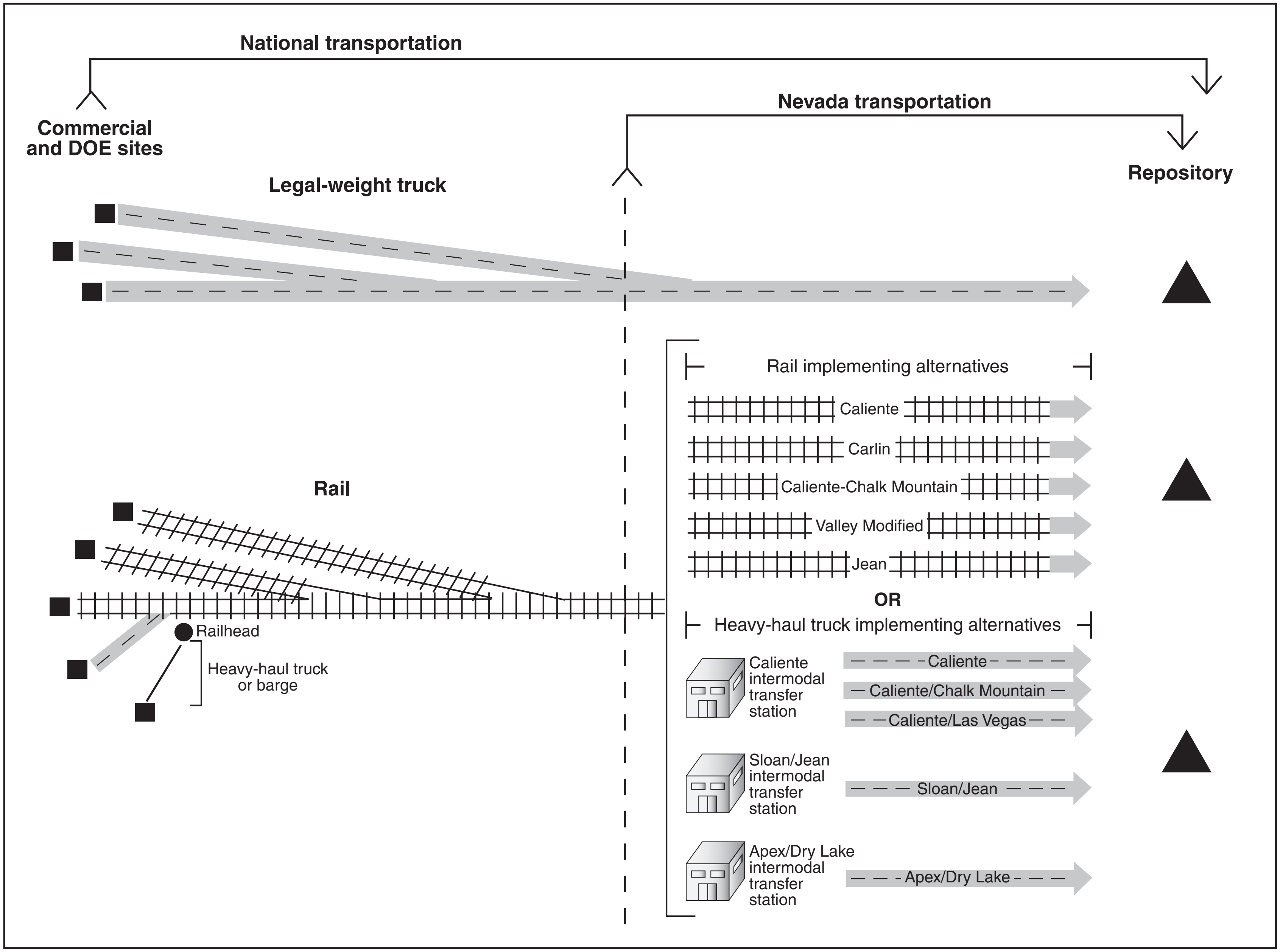

Figure 6-1. Relationship of Nevada and national transportation.

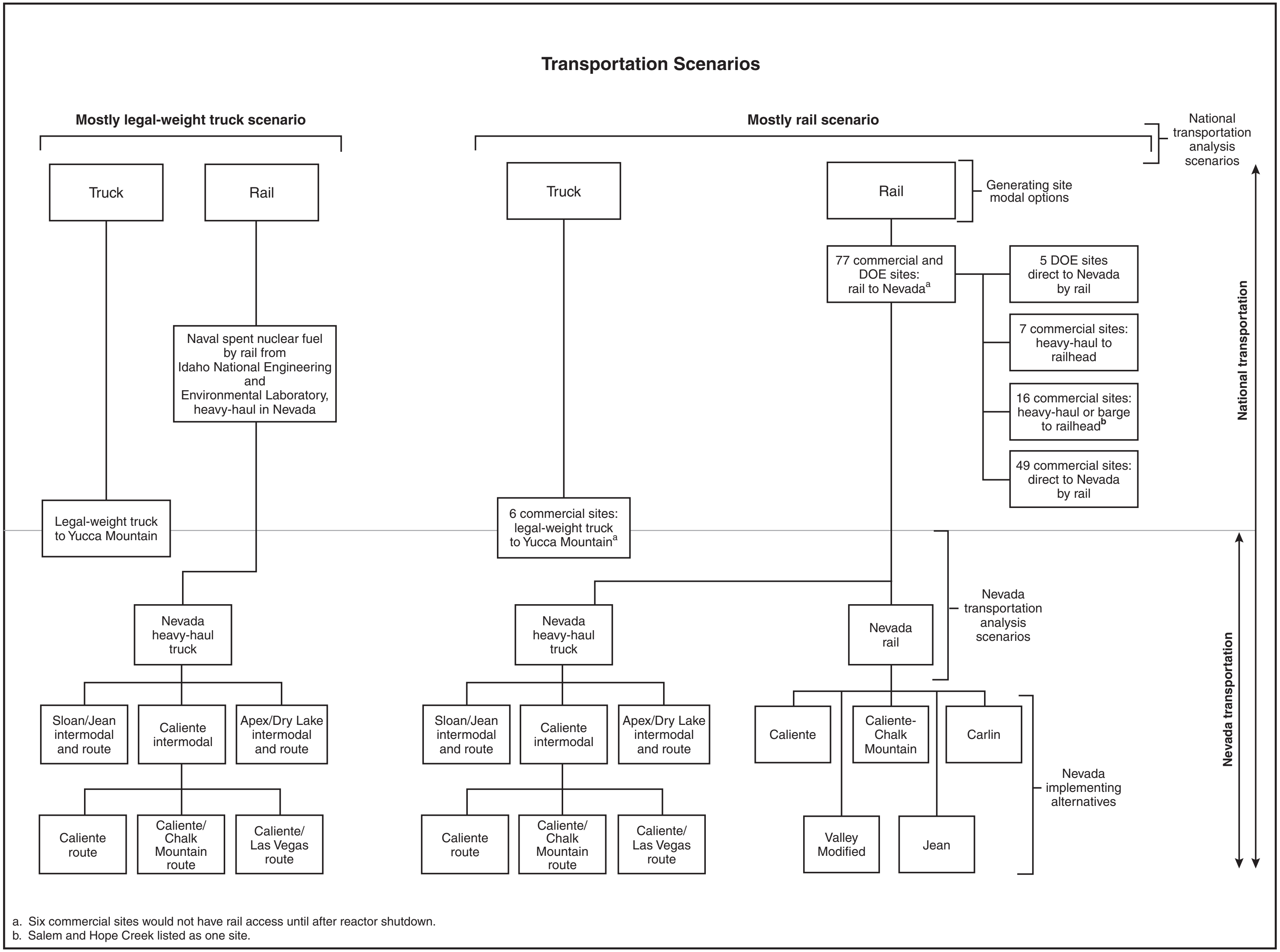

Figure 6-2. Relationship between transportation modes, national and Nevada analytical scenarios, and Nevada transportation implementing alternatives.

CHANGES SINCE THE PUBLICATION OF THE DRAFT EIS

Changes in Information, Analytic Tools, and Assumptions

Since the publication of the Draft EIS, DOE has acquired new information and analytic tools that contribute to an improved understanding of interactions between the potentially affected environment and transportation activities necessary for the Proposed Action, including information and suggestions for improvements provided in public comments on the Draft EIS and on the Supplement to the Draft EIS. As a consequence, the impacts described in this chapter, Appendix J, and other transportation-related sections of this Final EIS differ from those described in the Draft EIS.

Notably, estimates of total impacts to public health and safety described in this chapter are smaller than those in the Draft EIS. With the exception of consequences of postulated acts of sabotage, estimates for radiological impacts of *incident-free transportation* and accidents and consequences of maximum reasonably foreseeable accidents are all smaller than the estimates in the Draft EIS. The nonradiological impacts reported in this Final EIS are approximately the same as those in the Draft EIS, including those in the Supplement to the Draft EIS. Differences in estimates of transportation-related impacts for land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise; aesthetics; waste management; utilities, energy, and materials; and environmental justice are principally the result of new information that enabled better representation of impacts that were, for the most part, identified in the Draft EIS and, for land use, changes in the affected environment that occurred after the publication of the Draft EIS. The following paragraphs describe the changes that had the most effect on the impact results, including comparisons with the results presented in the Draft EIS.

Estimated Numbers of Shipments. Estimates of the number of shipments of commercial spent nuclear fuel that would be made under the mostly legal-weight truck and mostly rail scenarios were based on a version of the CALVIN computer program (DIRS 155644-CRWMS M&O 1999, all) that has been updated from the version used for the Draft EIS. The updated version of CALVIN (Version 2.0) incorporates a number of changes, including: (1) revised estimates of future generation of commercial spent nuclear fuel; (2) revised estimates of the capabilities of commercial generator sites to handle and load large shipping casks; (3) revised estimates of the types and sizes of shipping casks that would be used; and (4) revised assumptions about how sites would select spent nuclear fuel assemblies for delivery to DOE.

The Final EIS analyses used a total of about 53,000 legal-weight truck shipments and 300 rail shipments of naval spent nuclear fuel for the mostly legal-weight truck scenario. This is an increase of about 3,000 shipments or 6 percent over the approximately 50,000 shipments reported in the Draft EIS. This increase is the result of slight changes in the assumed characteristics of spent nuclear fuel that commercial generators would deliver to DOE.

For the mostly rail scenario, the total number of shipments in the Final EIS analyses is about 10,700. About 1,100 of these shipments would be by legal-weight truck. The Draft EIS used a total of about 13,400 shipments (about 25 percent more), of which about 10,800 would be by rail and 2,600 by legal-weight truck. The reduced number of shipments is a result of changes in assumptions regarding the size of shipping casks and the capabilities of generator sites to handle and load rail casks. For this scenario, based on information available from industry sources following the publication of the Draft EIS, the updated CALVIN analysis assumed three generator sites previously considered capable of handling and loading only legal-weight truck casks could handle and load rail casks. In addition, the analysis assumed that the remaining truck-only sites would be capable of handling and loading rail casks following permanent shutdown of the sites' reactors.

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Based solely on changes in the number of shipments, estimates of health and safety impacts nationally and in Nevada are 6 percent greater for the mostly legal-weight truck scenario and about 25 percent less for the mostly rail scenario than those reported in the Draft EIS. The change in the number of shipments would not cause discernible changes in impacts in other resource areas discussed in this chapter.

Characteristics of Commercial Spent Nuclear Fuel Used in Accident Analyses. The transportation analysis used the characteristics of representative spent nuclear fuel described in Appendix A, rather than the characteristics of typical (or average age) spent nuclear fuel used in the Draft EIS, to evaluate potential impacts and consequences of transportation accidents. Representative spent nuclear fuel is commercial spent nuclear fuel with a health and safety hazard that is the average of all the spent nuclear fuel that would be shipped to the proposed repository. Under this averaging, representative spent nuclear fuel would be (1) spent nuclear fuel from a pressurized-water reactor that had been discharged from a reactor for 15 years and had an average burnup of 50,000 megawatt-days per metric ton of heavy metal (MTHM), or (2) spent nuclear fuel from a boiling-water reactor that had been discharged for 14 years with a burnup of 40,000 megawatt-days per MTHM. Conversely, typical pressurized-water reactor spent nuclear fuel (also described in Appendix A) has been discharged from a reactor for 25.9 years with a burnup of almost 40,000 megawatt-days per MTHM. Typical boiling-water reactor spent nuclear fuel has been discharged from a reactor for 27.2 years with a burnup of about 32,000 megawatt-days per MTHM. DOE made the change to a representative fuel for accident analysis because it determined that estimates of accident risk using the characteristics of the typical spent nuclear fuel discussed in the Draft EIS underestimated the accident risk of shipments. This change in the analysis resulted in about a twofold increase in the estimated inventory of primary radionuclides in each shipping cask in comparison to the estimates in the Draft EIS. Primary radionuclides are those that contribute the most to impacts (see Appendix J, Section J.1.3.1).

Highway and Rail Routes. The analyses of transportation impacts in the Draft and Final EIS used the HIGHWAY (DIRS 104780-Johnson et al. 1993, all) and INTERLINE (DIRS 104781-Johnson et al. 1993, all) computer programs to identify routes that DOE could use for shipments from 77 generator sites to a Yucca Mountain Repository. DOE believes that the identified routes are representative of those that would be used if the Yucca Mountain site was approved and a repository was constructed and operated.

IDENTIFICATION OF TRANSPORTATION ROUTES

DOE has published proposed policy and procedures (63 *FR* 23756; April 30, 1998) "setting forth its revised plans for implementing a program of technical and financial assistance to states for training public safety officials of appropriate units of local government and to Indian tribes through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste." The proposed policy and procedures state that DOE "plans to identify preliminary routes [that the Department] anticipates using within state and tribal jurisdictions when it notifies governors and tribal leaders of their eligibility." Notification would begin "approximately five years prior to transportation through" affected jurisdictions.

Most of the routes used for analyses in the Final EIS did not change from those used for the Draft EIS. However, railroad consolidations and alternative preferred routes designated by states for highway shipments resulted in changes in some of the routes identified by the computer programs and used in the analyses. For example, railroad consolidation led to a change in a potential *rail route* from the Monticello generator site in Minnesota. This caused the State of South Dakota, which was not included among the states crossed by routes analyzed in the Draft EIS, to become one of the states through which the analysis assumed shipments would travel.

In the case of highway shipments, new information published by the U.S. Department of Transportation (65 *FR* 75771; December 4, 2000) lists 14 states that have designated preferred routes for truck shipments of Highway Route-Controlled Quantities of Radioactive Materials. The Draft EIS listed 10 states based on information available at the time. The four added states are Delaware, Ohio, Texas, and Utah. Also listed for the first time in an integrated source are route restrictions and preferred route designations made by the State of Colorado that would preclude the use of Interstate Highway 70 west of Denver to the Utah border. The new information resulted in changes in the routing that the Draft EIS analysis assumed for some shipments.

Overall, the effects of changes in the routes used in the analysis on estimated impacts would be small for national transportation. However, DOE has added maps and tables that show the routes that were analyzed and the estimated health and safety impacts for each state through which shipments would pass if these routes were used (Appendix J, Section J.4).

Bureau of the Census Data. The analyses in the Draft and Final EIS used the HIGHWAY and INTERLINE computer programs to develop estimates of potentially affected populations along transportation routes. These programs use block group data from the 1990 Census. The Draft EIS used estimates of population along routes provided by these programs to estimate radiological impacts of transportation nationally and in Nevada. In a change from the Draft EIS, the Final EIS analysis used projections for each state made by the Bureau of the Census for population growth to 2025, results of the 2000 Census, and extrapolation to estimate populations along routes in 2035. These estimated population increases were used in estimating radiological health and safety impacts for national transportation.

In another change, estimates of populations along potential routes in the State of Nevada incorporate information developed using a geographic information system, 1990 Census data, and projections to 2035 obtained using the REMI computer program. Projections using REMI were based on forecasts provided to DOE by Clark County, Nye County, and the Nevada State Demographer, anchored to the results of the 2000 Census for Nevada counties. In addition, population estimates for routes that include the planned Las Vegas Beltway used a forecast for 2020 provided by a report prepared for the City of North Las Vegas (DIRS 155112-Berger 2000, all).

The overall effect of these changes is that estimated affected populations along national routes would be about 40 percent greater than the populations estimated with the use of 1990 Census data, as used in the Draft EIS. The Nevada population used in the analysis of transportation-related health and safety impacts in this Final EIS is about 100 percent greater than that used in the Draft EIS.

DOE conducted a limited sensitivity analysis of national transportation impacts using route population information based on projections provided by the TRAGIS computer program (DIRS 157136-Johnson and Michelhaugh 2000, all). The TRAGIS program, which DOE released in the Fall of 2001 to replace the HIGHWAY and INTERLINE computer codes used for the transportation analyses in this EIS, uses 2000 Census data to develop population estimates for routes. Based on the sensitivity analysis performed using TRAGIS in place of HIGHWAY, DOE determined that doses to the general public from incident-free transportation would be similar to (about 10 percent greater than) those reported in this chapter.

Performance of Shipping Casks in Transportation Accidents. DOE has revised the transportation accident analyses in the EIS to reflect new information. For example, since the publication of the Draft EIS, the Nuclear Regulatory Commission published *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, all). Based on the analyses in that report, DOE concluded that the models used for analysis in the Draft EIS relied on assumptions about spent nuclear fuel and cask response to accident conditions that caused an overestimation of the resulting impacts. For example, the analyses in the Draft EIS were based on *Shipping Container Response to Severe Highway and Railway*

Assessment of the Hazards of Transporting Spent Nuclear Fuel and High-Level Radioactive Waste to the Proposed Yucca Mountain Repository Using the Proposed Northern Las Vegas Beltway **(DIRS 155112-Berger 2000, all)**

The transportation analyses in the Final EIS used some information from this document. DOE considers this report to be the only available source of some information, but is in broad disagreement with the analyses and conclusions regarding the report's estimates of impacts.

Useful information not available elsewhere includes:

- An estimate of population along the Las Vegas Beltway—an area that is currently mostly uninhabited—although, as discussed below, DOE believes the estimate is high.
- New information regarding the expected cost to construct the beltway.
- A scenario for estimating dose to a maximally exposed individual along a highway route used by heavy-haul trucks in Nevada.

DOE disagrees with some aspects of the report for a variety of reasons, including:

- The projected population growth within 3.2 kilometers (2 miles) of the 21-kilometer (13-mile)-long Northern Beltway appears to be very high, accounting for 42 percent of population growth projected by a University of Nevada Las Vegas report (DIRS 156031-Riddel and Schwer 2000, Table 1) for all of Clark County during the same period.
- The report uses a very high accident rate as a basis for accident probabilities. This rate—4 times that reported to DOE by the State of Nevada for interstate trucks on all Nevada highways (see Appendix J, Section J.1.4.2.3.3)—is 17 times greater than the rate DOE used in the EIS, which is based on statistics compiled by the U.S. Department of Transportation. The rate could be higher in part because it was based on the State of Nevada definition of an accident rather than the Department of Transportation definition recommended by the National Governors Association (see Sections J.1.4.2.3 and J.1.4.2.3.3). In addition, the rate used in the report appears to be an intercity rate (urban interstate) that does not accurately reflect the accident rate for highways in Nevada that shipments to Yucca Mountain would use.
- The report projects economic impacts in the Northern Beltway area assuming that business location decisions would be made solely on whether shipments of spent nuclear fuel and high-level radioactive waste would use the Northern Beltway. The report did not consider many other factors commonly associated with such decisions.
- The report overestimates economic impacts to Clark County under the implied assumption that not only would some companies not locate near the Northern Beltway because of shipments of spent nuclear fuel and high-level radioactive waste, these companies would not locate anywhere in Clark County; and that existing Clark County companies that could move to the Northern Beltway area would actually leave Clark County. The report ignores statistics that show that many business relocations occur in the same county. In addition, the report fails to recognize that decisions to remain at the same location would have no economic impact on the county.

Accident Conditions, which estimated that 99.4 percent of accidents would not lead to a release of radioactive materials from a shipping cask (DIRS 101828-Fischer et al. 1987, pp. 4-8, 7-25, and 7-26). Based on the revised analyses, casks would continue to contain spent nuclear fuel fully in more than 99.99 percent of all accidents (DIRS 152476-Sprung et al. 2000, p. 7-73 to 7-76). In addition, based on that report, DOE has included impacts of an accident in which the radiation shielding of a shipping cask would be damaged—so-called *loss-of-shielding* accidents. DOE also included estimated impacts of 99.99 percent of accidents in which the cask's containment and shielding would not be damaged by the accident but where nearby populations could be exposed to low-level radiation during the time it would take for accident response and recovery. The analysis assumed the low-level radiation would be the maximum allowed by regulation for a cask transporting spent nuclear fuel or high-level radioactive waste. The Draft EIS did not include these evaluations.

The collective effect of these changes was a significant reduction in estimated consequences of maximum reasonably foreseeable accidents and estimates of accident risk from those presented in the Draft EIS. In addition, the use of information from the DIRS 152476-Sprung et al. (2000, all) report permits a better description of the maximum reasonably foreseeable accidents analyzed. For example, the characteristics of the maximum reasonably foreseeable accident analyzed in this chapter for rail transportation correspond closely to reported conditions in the Baltimore Tunnel train accident fire in July 2001 (DIRS 156753-Ettlin 2001, all; DIRS 156754-Rascovar 2001, all).

Model for Estimating Doses to the Public at Truck Stops. The Draft EIS used information reported in DIRS 101888-Neuhauser and Kanipe (1992, p. 3-29) to estimate the radiation dose that would be received by members of the public at rest stops used by trucks carrying spent nuclear fuel and high-level radioactive waste. The time allocated to stops in the report is equivalent to about 1 hour of stop per hour of travel—a significant overestimate of stop time in real truck transport operations involving team drivers. As a consequence, more than 90 percent of the dose to the general public reported for the mostly legal-weight truck scenario in the Draft EIS was based on this estimate of dose to persons at truck stops.

The analysis in this Final EIS used more recent data based on field observations of truck stop time (DIRS 152084-Griego, Smith, and Neuhauser 1996, all). In addition, the analysis estimated doses to populations in areas surrounding stops, including estimates of stop time for state inspections and periodic driver walk-around, which were not part of the analyses in the Draft EIS. The analysis concluded that the average time trucks would stop would be about 1 hour for every 10 hours of travel, which resulted in a much lower estimate for radiation dose to the general public. Appendix J, Section J.1.3.2.1 provides additional information.

RADTRAN. DOE used the RADTRAN 4 computer program in estimating the radiological incident-free and accident risk impacts in the Draft EIS. For this Final EIS, DOE used an updated version of the program, RADTRAN 5, which allowed more complex analyses of impacts, such as those involving models used to estimate doses to persons at truck stops. With the exception of the improvements in capabilities afforded by RADTRAN 5, the analytical methods used by the two programs to estimate impacts to populations are largely the same. This change had no effect on the results.

Health Effect Fatality Impacts of Vehicle Emissions. New information used to estimate fatalities from health effects of vehicle emissions (DIRS 151198-Biwer and Butler 1999, all) became available following the publication of the Draft EIS. DOE used this information in conjunction with information from the Environmental Protection Agency (DIRS 155780-EPA 1993, all; DIRS 155786-EPA 1997, all) to develop risk factors for the analysis in this Final EIS. Based on this new data, estimates of impacts from vehicle emissions are about 3 times greater than the estimates in the Draft EIS, which ranged from 0.2 to 0.6 fatalities over 24 years.

First Responder. The analyses of transportation impacts in this Final EIS included estimates of doses to maximally exposed individuals not identified in the Draft EIS. These included estimates of doses to a first responder at a transportation accident and individuals who resided close to highways or rail routes in the State of Nevada.

Socioeconomic Baseline for Nevada Counties. The analyses of socioeconomic impacts in the Draft and Final EIS used baseline data developed using the REMI computer program. However, input parameters to calculations performed using REMI were adjusted for the Final EIS so predicted results reflect similar forecasts provided by Clark and Nye Counties and the Nevada State Demographer. The resultant changes in estimated socioeconomic impacts are small.

Time to Construct a Branch Rail Line. After the publication of the Draft EIS, the estimated time to construct a branch rail line to the Yucca Mountain site changed from 2.5 years (30 months) to 40 to 46 months, depending on the corridor. However, engineering estimates of materials and labor required for construction did not change, and therefore the constant-dollar cost estimates did not change. The changes in projected construction schedules led to lower estimates for socioeconomic impacts of constructing and operating a branch rail line in Nevada than those in the Draft EIS.

Cost to Construct the Las Vegas Beltway. The EIS includes estimates of socioeconomic impacts of using heavy-haul trucks on three candidate routes that include the planned Las Vegas Beltway. The analysis in the Draft EIS assumed an expenditure of $40 million (1998 dollars) for the northern segment of the Beltway, occurring between 2007 and 2010 rather than between 2010 and 2020 as planned by Clark County. The Draft EIS analysis also assumed a corresponding total of $90 million (1998 dollars) for the southern and western segments of the Beltway. An estimate in a City of North Las Vegas-sponsored report suggests the cost of completing the Northern Beltway between 2010 and 2020 could be as much as $425 million in 1998 dollars (DIRS 155112-Berger 2000, p. 29) ($463 million in 2001 dollars). DOE adopted this estimate for use in estimating socioeconomic impacts for the Caliente/Las Vegas and Apex/Dry Lake routes for heavy-haul trucks evaluated in this chapter. Using the same information, the analysis in this chapter estimated socioeconomic impacts for a Jean route for heavy-haul trucks with the assumption that the corresponding costs to complete the southern and western segments of the Beltway could be as much as $790 million. Because it assumed these larger estimated costs, the estimated socioeconomic impacts in Clark County for the Jean, Apex/Dry Lake, and Caliente/Las Vegas routes for heavy-haul trucks are higher in this Final EIS than those in the Draft EIS, but remain low for the County.

Potential Land-Use Conflicts for Construction and Operation of a Branch Rail Line in Nevada. After the publication of the Draft EIS, changes occurred in ownership and use of lands that a branch rail line in the candidate rail corridors in Nevada could cross. Land that could be crossed by the Bonnie Claire Alternate of the Caliente and Carlin Corridors has been transferred by an Act of Congress to the Timbisha Shoshone Tribe; land at the junction of the Stateline Pass Option of the Jean Corridor and the Union Pacific Railroad has been transferred by an Act of Congress to Clark County for development of the Ivanpah Valley Airport; and land near the junction of the Valley Modified Corridor and the Union Pacific Railroad has been transferred by the Bureau of Land Management to Clark County for the Apex Industrial Park. These changes result in potential land-use impacts for the affected corridors.

Changes Due to Public Comments. In response to interest and suggestions by the public and to better describe potential impacts of transportation alternatives in Nevada, DOE has modified analyses and presentations of impacts. The following are examples of such modifications:

- *Land-use and ownership.* Added available descriptive details and assessed potential impacts to wilderness study areas; grazing allotments; rights-of-way; and Bureau of Land Management, private, Nellis Air Force Range (now called the Nevada Test and Training Range), Native American, and Nevada Test Site lands along Nevada rail corridors, including variations, and along routes for heavy-haul trucks.

- *Air quality (nonradiological).* Provided more complete quantitative estimates of carbon monoxide and PM_{10} emissions from transportation activities, particularly in the Las Vegas Valley nonattainment area.

- *Hydrologic resources.* Expanded flood zone, groundwater, and surface-water resources, and water demand analyses to incorporate information for variations of Nevada rail corridors and for routes for heavy-haul trucks.
- *Biological resources and soils.* Provided more details from existing information and analyses of disturbed areas, sensitive biological resources, management areas, and soil impacts.
- *Cultural resources.* Acquired and evaluated additional cultural, archeological, and Native American data and included evaluations of potential impacts of Nevada rail variations and heavy-haul truck routes.
- *Socioeconomics.* Updated socioeconomic baseline information to accommodate 2000 Census information as well as match population forecasts provided by Clark and Nye Counties and Nevada State Demographer.
- *Noise and vibration.* Added new data and developed additional analyses of impacts of ground vibration and noise on *sensitive structures*, populations, and communities along Nevada rail corridors and routes for heavy-haul trucks.
- *Aesthetics.* Incorporated field observations made after the publication of the Draft EIS for viewsheds along candidate rail corridors and routes for heavy-haul trucks and used additional detail available from existing information.
- *Environmental justice.* Added available detail, reanalyzed data on minority and low-income populations, and reevaluated impact assessments of other disciplines.
- *Utilities, energy, and materials.* Reanalyzed impacts based on new information for the repository flexible design and for variations in the candidate rail corridors.
- *Waste management.* Added new waste data, details of waste sources and shipments, and changes in waste management from changes in information regarding the repository flexible design.

Other Changes

In addition to the changes described above, DOE added Appendix M to provide general background information on transportation-related topics that are not addressed in detail in this chapter or Appendix J and are not directly related to potential impacts of the Proposed Action. This includes information on the Department's planning, under a draft Request for Proposal, to issue shipping contracts and discussion of in-transit procedures, emergency response plans, indemnification against damages from the potential release of spent nuclear fuel and high-level waste, and cask testing.

6.1 Summary of Impacts of Transportation

6.1.1 Overview of National Transportation Impacts

This section provides an overview of the potential impacts of using the Nation's highways and railroads to transport spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites to the repository at Yucca Mountain. Detailed discussions of national transportation impacts are in Section 6.2 and analytical methods are in Appendix J. All potential impacts are related to the health and safety of populations and hypothetical maximally exposed individual members of the general public and workers. This summary includes estimated impacts from loading operations, incident-free transportation, and accidents for the mostly legal-weight truck and mostly rail national transportation scenarios. (National transportation includes transportation in Nevada to Yucca Mountain.)

Estimated national transportation impacts are based on 24 years of transportation activities during the Proposed Action and average annual shipments of about 2,200 (2,200 truck, 13 rail) for the mostly legal-weight truck scenario and about 450 (400 rail, 45 truck) for the mostly rail scenario. From all causes, about 8 fatalities could occur in the nationwide general population from transportation activities of the mostly legal-weight truck scenario and about 5 fatalities from the mostly rail scenario during the 24-year transportation period (impacts of a maximum reasonably foreseeable accident are not included).

Impact analyses for the transport of spent nuclear fuel and high-level radioactive waste in Nevada using a branch rail line are based on the assumption that the branch rail line would be dedicated to activities related to the Proposed Action. There are other possible uses for such a branch rail line in Nevada including support of ranching, industrial, and commercial endeavors; support of Federal, state, tribal and local government activities; and transport of people, materials, and products into, out of, and across the state. However, DOE has not addressed any of these possibilities because there are no concrete proposals at this time for alternative uses, and insufficient information exists to evaluate such uses. Potential uses of a branch rail line are identified in Chapter 8, but the need or level of use and growth of use has not been defined or evaluated. If the Yucca Mountain Site was designated, DOE would consider any uses that were reasonably foreseeable at that time other than transporting radioactive materials to the site in selecting an alignment within any rail corridor selected.

Impacts of Loading Operations

All spent nuclear fuel and high-level radioactive waste would be loaded onto trucks or railcars at the 77 sites for transport to the Yucca Mountain site. Some health and safety impacts would be associated with these loading operations. There would be small (0.04 latent cancer fatality) impacts to members of the public from loading operations. Over the 24 years of the Proposed Action, an estimated 6 and 2 latent cancer fatalities could occur in involved worker populations from radiation exposure for the mostly legal-weight truck and mostly rail scenarios, respectively. The probability of a latent cancer fatality to the maximally exposed involved worker would be about 0.005 for both scenarios. No worker fatalities from industrial accidents would be expected. No or very small impacts to workers or members of the public would be expected from postulated loading accidents. About 0.4 traffic fatality could occur in the worker population from commuting under the mostly legal-weight truck scenario, while about 0.2 traffic fatality could occur under the mostly rail scenario. Loading operations and potential impacts are discussed further in Section 6.2.2.

Impacts of Incident-Free Transportation

Incident-free transportation is the expected norm for transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. Impacts of incident-free transportation would include those from external radiation emitted from transportation casks and vehicle exhaust emissions along the transportation routes.

Over the 24 years of the Proposed Action, an estimated 3 (2.5) latent cancer fatalities could occur in the general population along transportation routes from radiation exposure under the mostly legal-weight truck scenario and an estimated 1 latent cancer fatality could occur under the mostly rail scenario. Under the mostly legal-weight truck and mostly rail scenarios, the probability of a latent cancer fatality to the maximally exposed member of the public would be no more than 0.0012 and 0.0001, respectively. Under these same scenarios, about 1 (0.95 for the mostly legal-weight truck scenario and 0.77 for the mostly rail scenario) fatality from vehicle emissions could occur in the general population along transportation routes.

IMPLEMENTING ALTERNATIVES AND SCENARIOS

Implementing alternatives and scenarios are used to describe the range of reasonably foreseeable transportation actions with environmental impacts that could result from the Proposed Action.

Implementing alternatives represent feasible selections that DOE could make based in part on this EIS (for example, selecting a branch rail line corridor or an intermodal transfer station location and an associated route for heavy-haul trucks). Analytical scenarios, on the other hand, are feasible combinations of actions that DOE would have limited ability to direct (for example selecting the use of rail or truck casks for shipments from a specific nuclear powerplant). The scenarios are selected such that the analysis results bound the range of impacts that could result from the Proposed Action.

The transportation modes that make up the analytical scenarios and implementing alternatives include the following:

Legal-weight truck transportation: Legal-weight trucks have gross vehicle weights, including cargo, that do not exceed 80,000 pounds, which is the loaded weight limit for commercial vehicles operated on Interstate and U.S. highways without special state-issued permits. In addition, these vehicles have dimensions that are within the constraints of Federal and state regulation limits.

Permitted overweight, overdimension truck transportation: Semi- and tandem tractor-trailer trucks with gross vehicle weights over 80,000 pounds must obtain permits from state highway authorities to use public highways. States often permit vehicles that have gross weights above 80,000 pounds as *overweight, overdimension* vehicles with operating restrictions to protect public safety. Seven-axle tractor-trailer trucks (steering axle and three drive axles on the tractor and three axles on the trailer) with weights greater than 80,000 pounds that meet Federal bridge formulas and dimensional limits can carry payloads of 70,000 pounds.

Rail transportation: Rail transportation includes railroad transportation of spent nuclear fuel and high-level radioactive waste in large rail transportation casks (rail casks). The casks would be placed on railroad cars at commercial and DOE sites or at nearby intermodal transfer facilities for shipment on trains operated by commercial railroad companies over existing tracks. Because of the weight of the casks, only one cask would be transported on a railcar.

Heavy-haul truck transportation: Heavy-haul truck transportation includes the movement of large rail casks—both loaded and empty—on large heavy-haul trucks traveling on existing highways. For the transportation of spent fuel and high-level radioactive waste rail casks, these vehicles would weigh as much as 500,000 pounds; they would be more than 100 feet long and 10 to 12 feet wide, and would stand as high as 15 feet above the road surface. Heavy-haul trucks would require special permits issued by a state transportation agency. The permits would normally restrict the times of operation (typically daylight, non-rush-hour), operating speeds, and highways used.

Barge transportation: Barge transportation would be the transportation of loaded and empty rail casks between a commercial facility and a nearby railhead using navigable waterways. Barge terminals would have intermodal transfer capabilities sufficient to transfer casks from barges to railcars.

An estimated 12 (11.7) latent cancer fatalities could occur in the worker population from radiation exposure for the mostly legal-weight truck scenario, and an estimated 3 (3.5) latent cancer fatalities could occur for the mostly rail scenario. The probability of a latent cancer fatality to the maximally exposed involved worker would be approximately 0.02 for either the mostly legal-weight truck or mostly rail scenario. DOE expects impacts to noninvolved workers to be even lower than those to involved workers. To assess potential radiological impacts at generator facilities, the EIS analysis assumed that noninvolved workers would have no direct involvement in handling spent nuclear fuel and high-level radioactive waste.

The differences in incident-free impacts between the mostly legal-weight truck and mostly rail scenarios are due principally to (1) the difference in the number of shipments for the two scenarios, and (2) differences in analysis assumptions about the numbers of in-transit stops, the number of potentially exposed persons, and their proximity to shipping casks that could result in external radiation exposure.

DOE identified no national environmental justice concerns or air quality impacts for incident-free transportation. Incident-free national transportation and the potential impacts to workers and the public are discussed further in Section 6.2.3.

Impacts of Transportation Accidents

The analysis evaluated impacts to human health and safety, collectively including the health and safety of the public and transportation workers, from transportation accidents. Thus, impacts to populations from transportation accidents would include impacts to affected workers. Because the population of transportation workers would be small compared to the general population, radiological accident risks and consequences for the worker population would be a small fraction of those estimated for the public (that is, the total population).

TRANSPORTATION ACCIDENT RADIOLOGICAL DOSE RISK

The risk to the general public of radiological consequences from transportation accidents is called *dose risk* in this EIS. Dose risk is the sum of the products of the probabilities (dimensionless) and the consequences (in person-rem) of all potential transportation accidents.

The probability of a single accident is usually determined by historical information on accidents of a similar type and severity. The consequences are estimated by analysis of the quantity of radionuclides likely to be released, potential exposure pathways, potentially affected population, weather conditions, and other information.

As an example, the dose risk from a single accident that had a probability of 0.001 (1 chance in 1,000), and would cause a population dose of 22,000 person-rem in a population if it did occur, would be 22 person-rem. If that population was subject to 1,000 similar accident scenarios, the total dose risk would be 22,000 person-rem. Using the conversion factor of 0.0005 latent cancer fatality per person-rem, an analysis would estimate a health and safety risk of 11 latent cancer fatalities from this population dose risk.

Accident impacts include the consequences where shipping casks could be breached with subsequent release of radioactive material to nearby individuals and populations. In addition, there could be impacts to individuals from “normal” traffic accidents, in which there would be no release of radioactive material from shipping casks and only those directly involved in the accident would be affected. The analysis examined radiological consequences under the maximum reasonably foreseeable accident scenario, and also estimated overall accident risk. The maximum reasonably foreseeable accident scenario is the one with the greatest potential consequences that are reasonably foreseeable. The scenario must also have an occurrence likelihood of 1 in 10 million per year or greater to be considered “reasonably foreseeable.” Accident risk considers the potential consequences of all foreseeable accident scenarios and their occurrence likelihood, ranging from accident scenarios that are likely to occur but would have no release of radioactive material to those accident scenarios that are extremely unlikely to occur but could have large consequences (for example, the maximum reasonably foreseeable accident scenario).

The overall radiological accident risk, as described in Appendix J, Section J.1.4.2.1, from all accident scenarios over the 24 years of transportation activities during the Proposed Action would be about 0.0002 latent cancer fatality for the mostly legal-weight truck scenario and about 0.0005 latent cancer fatality for the mostly rail scenario. These estimated latent cancer fatalities would occur in the hypothetically exposed population residing within 80 kilometers (50 miles) of the accident site.

The maximum reasonably foreseeable accident scenario for the mostly legal-weight truck scenario would result in about 1 latent cancer fatality in the exposed population. It is postulated to involve a release of radioactive material from a truck cask in an urbanized area under stable weather conditions. The probability of this accident scenario would be about 0.00000023 per year (a rate of about 2.3 in 10 million years). The maximum reasonably foreseeable accident scenario for the mostly rail scenario would result in about 5 latent cancer fatalities in the exposed population. It is postulated to involve a release of radioactive material from a rail cask in an urbanized area under stable weather conditions. The probability of this accident scenario would be about 0.00000028 per year (a rate of about 2.8 in 10 million years). The probability of a latent cancer fatality occurring in the hypothetical maximally exposed individual would be about 0.0015 for the mostly legal-weight truck scenario and about 0.015 for the mostly rail scenario.

DOE evaluated accidents involving the crash of a jet airliner into a legal-weight truck cask or rail cask (DIRS 157210-BSC 2001, all). Such an accident could result in up to 0.65 latent cancer fatality.

Nationwide, during the 24 years of the Proposed Action transportation activities, about 5 nonradiological fatalities could result from traffic accidents under the mostly legal-weight truck scenario. For the same time period, about 3 nonradiological fatalities could also result from traffic accidents under the mostly rail scenario. These fatalities would all be related to physical injuries associated with traffic accidents, not radiological impacts.

No environmental justice concerns were identified for transportation accident scenarios. Transportation accident scenarios and potential impacts are discussed further in Section 6.2.4.

Table 6-1 summarizes the national impacts of transporting spent nuclear fuel and high-level radioactive waste from 77 generator sites to the proposed Yucca Mountain Repository. The table lists impacts for the two transportation scenarios—mostly legal-weight truck and mostly rail. It includes impacts that would occur in Nevada among the national impacts. For the mostly rail scenario, Table 6-1 lists a range of impacts. Ten unique national impacts comprise the range—one for each of the five rail and five heavy-haul truck implementing alternatives in Nevada.

As listed in Table 6-1, impacts to the general population would be small for both scenarios. For example, impacts to individuals in a population of between 10 million and 17 million who lived within 800 meters (0.5 mile) of routes and to individuals who used the routes could range from about 0.12 millirem to as much as 0.5 millirem over the 24-year shipping campaign. These small doses would increase the risk of cancer for an average individual who lived along a route by 0.5 to 2.5 in 10 million over the individual's lifetime. This level of health and safety risk would not be discernible. A hypothetical maximally exposed individual who would live or work along transportation routes for 24 years would receive a dose of 2.4 rem (a truck stop worker for the mostly legal-weight truck scenario) or 0.29 rem (a person who lived near a rail stop for the mostly rail scenario). The estimated dose to the hypothetical truck stop worker would increase the risk of a latent cancer fatality by about 1 in 1,000 over the person's lifetime. For the maximally exposed individual who lived near a rail stop, the risk of a latent cancer fatality would increase by about 1 in 10,000 over the person's lifetime. The health and safety risks for these hypothetical individuals would not be discernible. For perspective, in the United States, about one in four deaths is caused by cancer from all causes.

Table 6-1. National transportation impacts for the transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail and mostly legal-weight truck scenarios.[a,b]

Group	Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Worker	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	48[c]	48[c]
	Individual latent cancer fatality probability	0.02	0.02
	Collective dose (person-rem)	29,000	7,900 - 8,800
	Latent cancer fatality incidence	11.7	3.2 - 3.5[d]
	Industrial safety (fatalities)	0.9	0.29
Public	*Incident-free health impacts, radiological*		
	Average exposed individual (rem)	0.0005	0.0001
	Maximally exposed individual (rem)	2.4[e]	0.29
	Individual latent cancer fatality probability	0.0012	0.00014
	Collective dose (person-rem)	5,000	1,200 - 1,600
	Latent cancer fatality incidence	2.5	0.61 - 0.81
	Incident-free vehicle emissions impacts (fatalities)	0.95	0.55 - 0.77
	Radiological impacts from maximum reasonably foreseeable accident scenario		
	Frequency (per year)	2.3 in 10,000,000	2.8 in 10,000,000
	Maximally exposed individual (rem)	3	29
	Individual latent cancer fatality probability	0.0015	0.015
	Collective dose (person-rem)	1,100	9,900
	Latent cancer fatality incidence	0.55	5
	Accident dose risk (person-rem)	0.46	0.89
	Accident risk (latent cancer fatalities)	0.00023	0.00045
Public and transportation workers	*Fatalities from vehicular accidents*	4.9	2.3 - 3.1

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operation, including impacts of loading.
c. Based on 2-rem-per-year dose limit.
d. Range for the 10 rail and heavy-haul truck implementing alternatives in Nevada.
e. Based on 100-millirem-per-year dose limit.

Radiological impacts of transportation accidents, which DOE estimated by summing the products of the probability of releases of radioactive materials from casks and the consequences of the releases if they occurred, would be very small. They would be small because accidents that could cause a release from a cask would be very unlikely and consequences from the small releases that could occur would generally be small. For example, Table 6-1 lists the consequences of maximum reasonably foreseeable accidents for the mostly rail and mostly legal-weight truck scenarios. In these accidents, which would have an annual likelihood of 2.3 in 10 million for the legal-weight truck scenario and 2.8 in 10 million for the mostly rail scenario, the estimated consequences would be 1,100 person-rem for a truck accident and 9,900 person-rem for a rail accident. The health and safety consequences of these doses would be about 0.55 latent cancer fatality for the truck accident and 5 latent cancer fatalities for the rail accident. The risk impacts of these accidents would be 2.3 in 10 million multiplied by 1,100 person-rem for the truck accident—about 0.00025 person-rem—and about 2.8 in 10 million multiplied by 9,900 person-rem for the rail accident—about 0.0028 person-rem. A *dose risk* of 0.0028 person-rem to a population is equivalent to a risk of 1 in 1 million of a single latent cancer fatality in the population. Thus, the radiological risks to health and safety from transportation accidents would be exceedingly small for both scenarios.

The radiological risks of accidents for the general public are not comparable with the risks of fatalities associated with immediate nonradiological consequences of transportation accidents. For the mostly legal-weight truck scenario, the analysis estimated there could be as many as 5 (4.9) fatalities over 24 years from vehicle collisions and other traffic accidents during the 53,000 legal-weight truck and 300 rail shipments. For the mostly rail scenario, which would involve as many as 9,600 rail and 1,100 legal-weight truck shipments, the analysis estimated there could be about 3 (2.5 to 3.3) fatalities over 24 years attributable to train operations; these could include fatalities from grade-crossing accidents and trespassers struck and killed by trains.

The analysis estimated long-term health effects fatalities that could be caused by the exhaust and fugitive dust emissions of the vehicles that would transport spent nuclear fuel and high-level radioactive waste. There would be 1 (0.95) fatality under the mostly legal-weight truck scenario and less than 1 (between 0.55 and 0.77) fatality under the mostly rail scenario as a consequence of 24 years of transportation. These fatalities would be latent, or would occur well after exposure to the vehicle exhaust and dust emissions.

Radiological doses to the workers who would load casks, drive trucks, operate trains, and inspect vehicles in transit would be higher than doses to the general public. Radiological protection programs would manage and limit doses to workers whose jobs would cause them to receive the greatest exposures. Even so, the analysis assumed a maximally exposed individual worker could receive a dose as high as 2 rem per year for each of the 24 years of the Proposed Action, for a total of 48 rem over 24 years. The analysis assumed that this dose, which is the maximum currently allowed under DOE administrative controls, would occur for both the mostly legal-weight truck and mostly rail scenarios. A dose of 48 rem would increase the worker's lifetime risk of a latent fatal cancer from an average of 23 percent from all causes to 25 percent.

The radiological impacts to all workers involved in shipping spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository would be greatest for the mostly legal-weight truck scenario. For this scenario, the analysis estimated the workers would receive a total dose of 29,000 person-rem. Thus, the estimated lifetime impact to the worker population for the mostly legal-weight truck scenario would be 11.7 latent cancer fatalities from shipments over the 24 years of the Proposed Action. For the mostly rail scenario, the estimated lifetime impacts would be between 7,900 and 8,800 person-rem, or about one-third of the impacts for the mostly legal-weight truck scenario.

6.1.2 OVERVIEW OF NEVADA TRANSPORTATION IMPACTS

This section provides an overview of the environmental impacts associated with transportation of spent nuclear fuel and high-level radioactive waste in the State of Nevada. Although this section provides a more detailed, regional subset of some of the information gathered and analyses conducted for national transportation (see Section 6.1.1), it also includes information analyzed specifically for Nevada. This includes impacts from construction and operation of branch rail lines, routes for heavy-haul trucks and intermodal transfer stations, commuter transportation for construction and operations activities, and transportation of other materials in support of Yucca Mountain operations. Detailed discussions of potential impacts in Nevada are in Section 6.3 and Appendix J. The following areas were evaluated for potential impacts in Nevada from Yucca Mountain transportation activities:

- Transporting spent nuclear fuel and high-level radioactive waste by legal-weight truck in Nevada
- Constructing a branch rail line in Nevada and using it to transport spent nuclear fuel and high-level radioactive waste by rail to the repository
- Upgrading highways in Nevada for use by heavy-haul trucks to transport spent nuclear fuel and high-level radioactive waste to the repository
- Constructing and operating an intermodal transfer station in Nevada
- Transporting materials, consumables, supplies, equipment, waste, and people to support construction, operation and monitoring, and closure of the repository

Overviews are presented for the 12 environmental resource areas analyzed in this chapter and for the transportation of other materials and supplies, which is presented in further detail in Appendix J. Section 6.3 contains summaries that provide information for assessing the relative impacts in these resource areas from the mostly legal-weight truck transportation scenario, the five implementing alternatives for rail transportation, and the five implementing alternatives for heavy-haul truck transportation.

6.1.2.1 Land Use

Land-use impacts (land areas that would be disturbed or whose ownership or use would change) would be greatest for the mostly rail scenario. Land-use and ownership impacts based on a 60-meter- (200-foot)-wide rail right-of-way (land withdrawn) would affect from approximately 9.4 square kilometers (2,323 acres) for the Valley Modified route to 33.2 square kilometers (8,204 acres) for the Caliente route. Actual land disturbance in each 400-meter- (0.25-mile)-wide corridor for individual rail routes would range from approximately 5.1 square kilometers (1,260 acres) for the Valley Modified route to approximately 19.2 square kilometers (4,744 acres) for the Carlin route (see Figure 6-3). DOE based these estimated disturbances on anticipated construction activities (borrow areas, construction camps, soil areas) in the 400-meter corridor associated with the construction of a railroad and the projected width of the average construction disturbance for each rail bed. The average disturbance widths, for example, range from approximately 28 meters (91 feet) for the Caliente-Chalk Mountain Corridor to approximately 37 meters (120 feet) for the Jean Corridor. Land disturbance calculations do not include access roads. Existing roads would be used where possible. Due to possible variations along the rail corridors, land-use, ownership, and disturbances could vary from those discussed above (see Appendix J, Section J.3.1.2). Section 6.3.2.2 reports ranges due to these variations, as well as information on the representative corridor routes. No prime farmland would be affected by any of the transportation routes. The Carlin Corridor would affect the most private land [14 square kilometers (3,459 acres)]. Table 6-2 summarizes the land-use conflicts along the corridors. Selecting variations of a corridor, as described in Appendix J, Section J.3.1.2, could reduce some conflicts and increase or change conflicts in others. Overall impacts are generally proportional to the length of the corridor.

Disturbed land area for all of the heavy-haul truck implementing alternatives would range from 0.83 to 3.6 square kilometers (205 to 890 acres). No more than 0.2 square kilometer (50 acres) of private land would be affected for any route. There would be no land-use impacts from legal-weight trucks using existing highways. Land-use impacts are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively. None of the transportation implementing alternatives currently being considered would be affected by the flexible design evaluated for the proposed repository. Chapter 2, Table 2-7, summarizes the impacts to the various resource areas as the result of the repository operating modes. Section 6.3 contains summary information about the impacts in Nevada from the mostly legal-weight truck scenario and the rail and heavy-haul alternatives of the mostly rail scenario.

There are potential land-use conflicts for the Nevada implementing alternatives. The Carlin, Caliente, and Valley Modified Corridors encroach on the western and southern boundaries of the Nellis Air Force Range (also known as the Nevada Test and Training Range), and the Caliente-Chalk Mountain rail corridor and Caliente/Chalk Mountain heavy-haul truck route travel through the Range from north to south, essentially bisecting it. The U.S. Air Force has stated to DOE that the construction and use of routes through the Nellis Air Force Range would seriously affect sensitive and classified programs, would severely reduce Air Force training capabilities, and would impair the ability to comply with international testing and training obligations on the Range. In response to these concerns, DOE has identified the Caliente-Chalk Mountain Corridor and Caliente/Chalk Mountain heavy-haul route as nonpreferred alternatives. In addition, the Air Force noted the potential for safety risks of using other routes that could cross lands that are hazard areas and encompass weapons safety footprints for live weapons deployment. Although DOE is unaware of specific safety risks, the Caliente, Carlin, and Valley Modified rail corridors

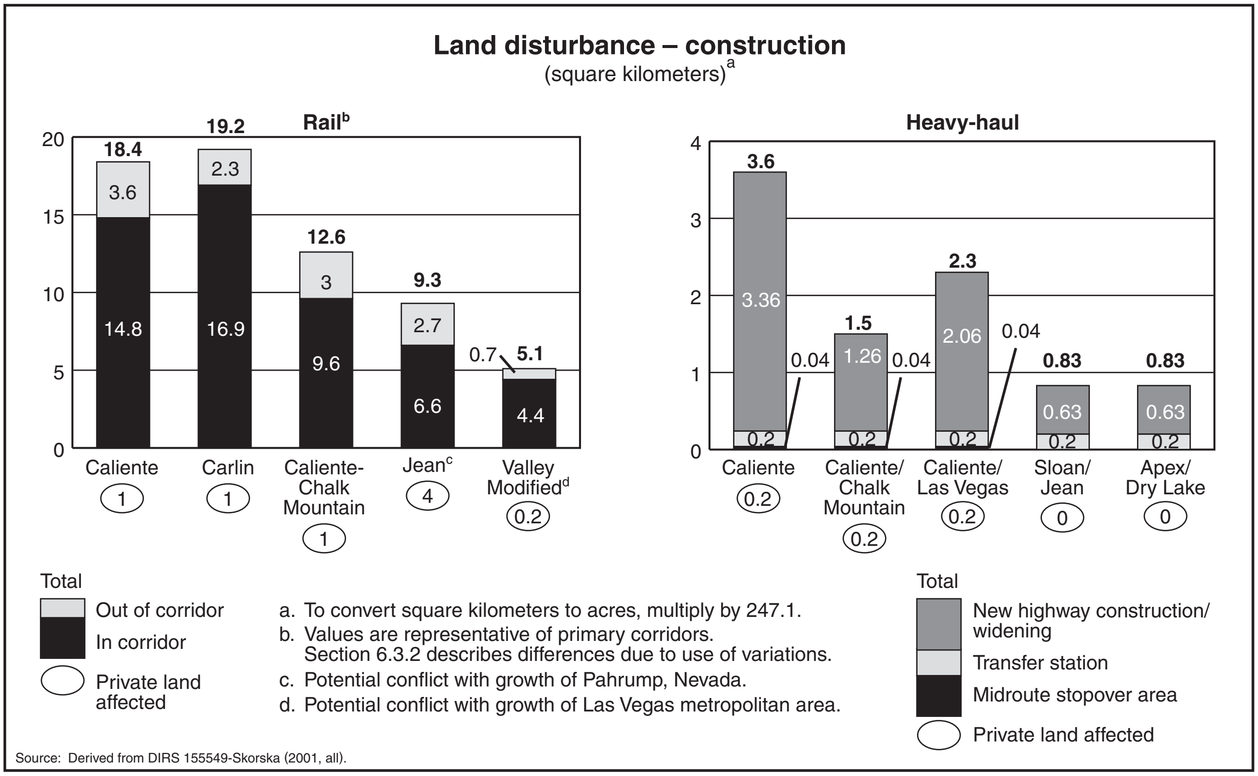

Figure 6-3. Land disturbed for construction of branch rail lines and upgrades to Nevada highways for heavy-haul use.

include sections that would encroach on the Range for short distances. For the Caliente Corridor, Carlin Corridor, and one section of the Valley Modified Corridor, DOE has identified variations that would avoid entering the Range. A short segment of the Valley Modified Corridor for which there is no currently identified variation would cross the southern Range boundary. If DOE selected this corridor, it would consult with the Air Force to determine avoidance or mitigation measures.

The Steiner Creek Alternate of the Carlin Corridor passes just west of the Simpson Park Wilderness Study Area and might encroach slightly into the Wilderness Study Area. The Caliente Corridor passes close to the Weepah Springs and Kawich Wilderness Study Areas, and passes inside and along the western boundary of the South Reveille Wilderness Study Area. The Wilson Pass Option of the Jean Corridor passes through Bureau of Land Management Visual Resource Management Class II lands in the vicinity of Wilson Pass in the Spring Mountains. The Jean and Valley Modified Corridors could have conflicts with the future community growth of Pahrump and Las Vegas, respectively. The Valley Modified Corridor passes near the Las Vegas Paiute Indian Reservation. The Valley Modified Corridor and its Sheep Mountain Alternate cross Nellis Wilderness Study Areas A, B, and C; the Quail Mountain Wilderness Study Area; and penetrates the Desert National Wildlife Refuge. The routes for heavy-haul trucks pass through the Las Vegas Paiute Indian Reservation along U.S. Highway 95 northwest of Las Vegas and approximately 4.8 kilometers (3 miles) west of the Moapa Indian Reservation. The rail origination location for the Stateline Pass Option is on lands to be used for the construction of the Ivanpah Valley Airport (Ivanpah Valley Airport Public Lands Transfer Act, Public Law 106-362, 114 Stat. 1404). The Bonnie Claire Alternate of the Carlin and Caliente Corridors passes through the newly established Timbisha Shoshone trust lands near Beatty.

Table 6-2. Land-use conflicts of rail corridor variations.[a,b]

Corridor[c]	Forest Service land	Fish and Wildlife Service land/ range	Desert Land Entry Program/ withdrawal area	Right-of-way/ road	Wilderness Study Area	Private land	Grazing allotments	Nellis Air Force Range	BLM[d]/ Nevada Test Site land	Native American Reservation
Caliente										
Caliente Corridor with Eccles Option	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Eccles Option	No	No	No	No	No	Yes	Yes	No	Yes	No
Caliente Option	No	No	No	Yes	No	Yes	No	No	Yes	No
Crestline Option	No	No	No	Yes	No	Yes	No	No	Yes	No
White River Alternate	No	No	No	No	No	Yes	No	No	Yes	No
Garden Valley Alternate	No	No	No	Yes	No	Yes	No	No	Yes	No
Mud Lake Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Goldfield Alternate	No	No	No	No	No	Yes	Yes	No	Yes	No
Bonnie Claire Alternate	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes
Oasis Valley Alternate	No	No	No	No	No	Yes	Yes	No	Yes	No
Beatty Wash Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Carlin										
Carlin Corridor with Big Smoky Valley Option	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Big Smoky Valley Option	No	No	Yes	Yes	No	No	Yes	No	Yes	No
Crescent Valley Alternate	No	No	No	Yes	No	Yes	Yes	No	Yes	No
Wood Spring Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Rye Patch Alternate	No	No	No	Yes	No	No	Yes	No	Yes	No
Steiner Creek Alternate	No	No	No	No	Yes	No	Yes	No	Yes	No
Monitor Valley Option	No	No	Yes	Yes	No	No	Yes	No	Yes	No
Mud Lake Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Gold Field Alternate	No	No	No	No	No	Yes	Yes	No	Yes	No
Bonnie Claire Alternate	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes
Oasis Valley Alternate	No	No	No	No	No	Yes	Yes	No	Yes	No
Beatty Wash Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Caliente-Chalk Mountain										
Caliente-Chalk Mountain Corridor with Eccles Option	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Eccles Option	No	No	No	No	No	Yes	Yes	No	Yes	No
Caliente Option	No	No	No	Yes	No	Yes	No	No	Yes	No
Crestline Option	No	No	No	Yes	No	Yes	No	No	Yes	No
White River Alternate	No	No	No	No	No	Yes	No	No	Yes	No
Garden Valley Alternate	No	No	No	Yes	No	Yes	No	No	Yes	No
Orange Blossom Road Option	No	No	No	Yes	No	No	No	No	Yes	No
Mercury Highway Option	No	No	No	No	No	No	No	No	Yes	No
Topopah Option	No	No	No	No	No	No	No	No	Yes	No
Mine Mountain Alternate	No	No	No	No	No	No	No	No	Yes	No
Area 4 Alternate	No	No	No	Yes	No	No	No	No	Yes	No
Jean										
Jean Corridor with Wilson Pass Option	No	No	No	Yes	No	Yes	Yes	No	Yes	No
Wilson Pass Option	No	No	No	Yes	No	Yes	Yes	No	Yes	No
North Pahrump Alternate	No[e]	No	No	Yes	No	Yes	No	No	Yes	No
Stateline Pass Option	No	No	Yes	Yes	No	Yes	Yes	No	Yes	No
Valley Modified										
Valley Modified Corridor	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Indian Hills Alternate	No	Yes	Yes	Yes	No	No	No	No	Yes	No
Sheep Mountain Alternate	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No
Valley Connection	No	No	No	No	No	Yes	No	No	Yes	No

a. Sources: Derived from DIRS 101504-BLM (1979, all), DIRS 103077-BLM (1983, all), DIRS 101523-BLM (1994, all), DIRS 103079-BLM (1998, all), DIRS 104993-CRWMS M&O (1999, all), DIRS 155549-Skorska (2001, all).

b. For definition and illustration of Corridor, Option, Variation, and Alternative terms, see Chapter 3, Section 3.2.2. For additional explanation, see Appendix J, Section J.3.1.2.

c. The first line under each corridor indicates land-use conflicts for the entire corridor with the use of that particular variation. Further listings indicate conflicts only along the length of the particular variation.

d. BLM = Bureau of Land Management.

e. Route abuts Toiyabe National Forest.

6.1.2.2 Air Quality

The main air pollutants would be fugitive dust (PM_{10}) and equipment emissions (carbon monoxide, nitrogen dioxide, and sulfur dioxide) from construction or upgrade activities associated with the rail and heavy-haul truck implementing alternatives, and vehicle emissions associated with legal-weight truck, heavy-haul truck, and rail transportation.

Because the Las Vegas air basin is in nonattainment of air quality regulations for PM_{10} and carbon monoxide, more restrictive regulations are applied to these criteria pollutants within the Las Vegas air basin. Construction activities are a major source of PM_{10} emissions (DIRS 155557-Clark County 2001, all). Vehicle emissions are the major source of carbon monoxide emissions (DIRS 156706-Clark County 2000, all). The transportation air quality analyses focused on these pollutants and sources within the Las Vegas air basin. Annual emissions were estimated and compared to the General Conformity threshold levels established in EPA regulations implementing the Clean Air Act.

The PM_{10} emissions during construction activities would result primarily from earthmoving operations, but also from construction vehicle fuel combustion. Dust control measures are required for activities in the Las Vegas air basin (DIRS 155557-Clark County 2001, all). These measures include water application and limiting activity on windy days. Construction activities would occur under the rail and heavy-haul transportation implementing alternatives in Nevada. The General Conformity threshold level for PM_{10} (63,500 kilograms per year) would be exceeded under the mostly rail scenario for total estimated emissions of the Valley Modified Corridor (190 percent of threshold). Construction activities in other corridors would not exceed the PM_{10} threshold. The General Conformity threshold level for PM_{10} would be exceeded under the heavy-haul scenario for the Caliente-Las Vegas route (100 percent of threshold). Construction activities of other heavy-haul routes would not exceed the PM_{10} threshold.

Carbon monoxide emissions would largely be a result of vehicle emissions. The greatest vehicle emissions under all three transportation scenarios would result not from radioactive material transport to Yucca Mountain, but from commuter and materials transportation to the site. Transport of personnel and materials results indicate maximum emissions during the operations and monitoring phase (67 percent of the carbon monoxide threshold). Vehicle emissions from transportation of radioactive materials would be, at most, 14 percent of the threshold level for the Valley Modified Corridor. During the construction phase, current estimates of fuel use for construction vehicles would result in exceedances of the General Conformity threshold levels for construction of the Valley Modified Corridor (110 percent of threshold).

Section 6.1.3 discusses air quality impacts from the transportation of personnel and materials. Section 6.3.1 discusses air quality impacts for Nevada legal-weight truck transportation. Sections 6.3.2 and 6.3.3 discuss rail and heavy-haul truck implementing alternatives, respectively.

DOE has conducted a separate conformity review for the Nevada transportation implementing alternatives that could result in the release of pollutants to the Las Vegas air basin, which is in nonattainment for carbon monoxide and PM_{10} (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54). Sections 6.3.1.1, 6.3.2.1, and 6.3.3.1 summarize the results of conformity reviews for legal-weight truck, rail, and heavy-haul truck transportation, respectively, in Nevada.

6.1.2.3 Hydrology

Surface-water resources are most prevalent among the Caliente and Carlin Corridors and could be affected by construction activities. The potential Caliente intermodal transfer station is about 0.19 kilometer (0.12 mile) from a perennial stream, and the Caliente, Caliente/Chalk Mountain, and Caliente/ Las Vegas routes for heavy-haul trucks would pass within 1 kilometer (0.6 mile) of water resources. Surface-water impacts during construction would be avoided by implementing good management practices to prevent and mitigate spills of pollutants and would avoid, minimize, or otherwise mitigate possible changes to stream flows. Therefore, DOE does not anticipate impacts to surface waters from the construction of a rail or heavy-haul truck implementing alternative. In addition, surface-water impacts would be unlikely from legal-weight truck, rail, or heavy-haul truck operations or the operation of an intermodal transfer station.

Potential for groundwater impacts would be limited. There would be the potential for temporary withdrawals of water from groundwater sources during the construction of a branch rail line or upgrades to highways and construction of an intermodal transfer station. Estimated water use would be greater for construction of branch rail lines than for upgrades for routes for heavy-haul trucks (see Figure 6-4). Such withdrawals would require temporary permits from the State of Nevada or possibly leases of temporary water rights from individuals along the route. If groundwater could not be withdrawn for construction, water would be transported from permitted sources to the construction sites by truck.

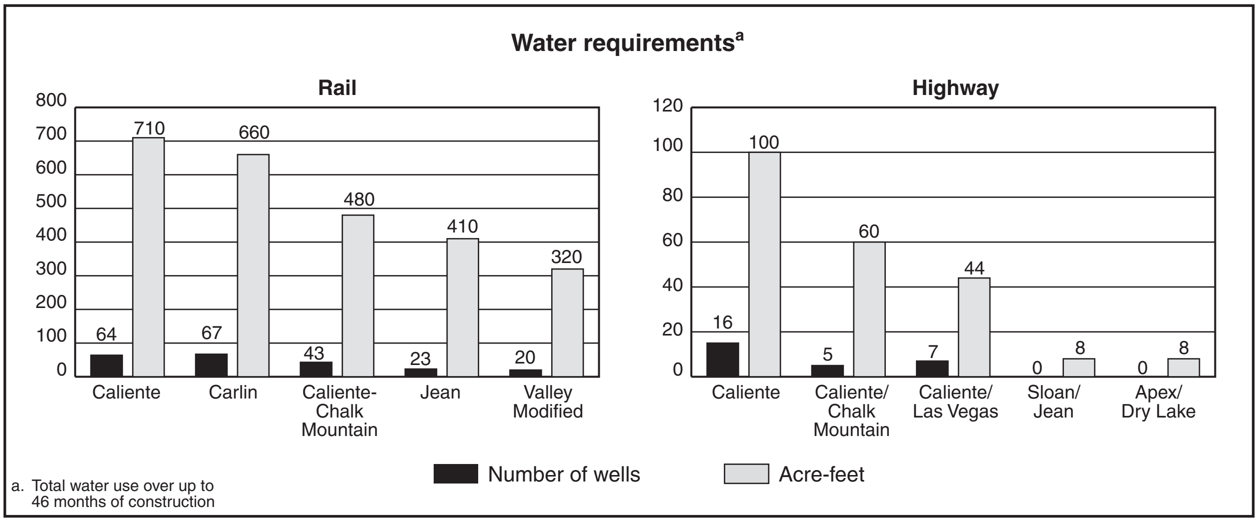

Figure 6-4. Water and number of wells required for construction of branch rail lines and upgrades to Nevada highways for heavy-haul use.

Legal-weight truck shipments, operations of a branch rail line, or operations of heavy-haul trucks, including the operation of an intermodal transfer station, would not affect groundwater resources. Water needs for these operations would be minor, and there would be little potential for contaminant releases to occur, particularly releases of a magnitude that could affect groundwater. Hydrology impacts are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively.

6.1.2.4 Biological Resources and Soils

Loss of habitat from construction of a branch rail line would be the greatest potential impact to biological resources (vegetation, habitat, threatened and endangered species, small animals, birds, game animals, wild horse and wild burro herds, and soils), potentially affecting the desert tortoise, a threatened species. Loss of desert tortoise habitat would be approximately 2.4 square kilometers (590 acres) for the Caliente/Chalk Mountain route, 3 square kilometers (740 acres) for the Caliente and Carlin routes, 5 square kilometers (1,200 acres) for the Valley Modified route (which is within the range of the desert tortoise along its entire length), and more than 11 square kilometers (2,700 acres) for the Jean route. All of these potential routes have low abundance of desert tortoises with the exception of some limited areas of the Jean route where abundance is higher.

In general, the number of herd management areas crossed by each route is related to the length of the route (as described in Section 3.2.2.1.4). Therefore, the potential for impacts to game animals or horses and burros through disruption of movement patterns or from loss of individual animals would be greater for the longer routes. The Valley Modified route does not cross any herd management areas, but passes through the Desert National Wildlife Range. The Carlin route passes through or near the greatest number of herd management areas or other areas that provide habitat for important biological resources (such as sage grouse strutting grounds). The adverse impact that loss of an individual animal could have on a particular herd would depend on the particular individual that was lost and the size of the herd. Small herds could be affected to a greater degree than large herds. Noise from passing trains could disturb game animals, horses, or burros until those animals became acclimated to the presence of the trains. DOE anticipates that two trains could pass by each day, so this disruption should be minimal.

Other features of the particular routes could affect the potential for impacts to biological resources along each route. Fencing along portions of a route could affect the number of individual animals lost because animals could be blocked from escape routes in fenced areas. Tunnels along the Jean route could be used by wildlife for shelter. Animals seeking shelter in a tunnel might not be able to escape if a train passed through while they were in the tunnel.

The potential for impacts from upgrading Nevada highways for heavy-haul truck use would be small because modifications to roads would occur in previously disturbed rights-of-way. An intermodal transfer station constructed in association with a heavy-haul truck implementing alternative would potentially disturb only about 0.2 square kilometer (50 acres) of potential desert tortoise habitat. The activities associated with constructing a branch rail line, building an intermodal transfer station, or upgrading and maintaining a heavy-haul truck route to Yucca Mountain would be likely to adversely affect a few individual desert tortoises. However, based on review of past experience and available information, DOE believes it could mitigate the impacts of these activities such that they would not negatively affect regional populations of desert tortoises, jeopardize the continued existence of the species, or result in adverse modification of designated critical habitat. Individuals of other special status species could be affected based on the route chosen. Impacts from operations, with the exception of infrequent wildlife kills by vehicles, would be unlikely. Although the proposed routes for heavy-haul trucks pass near or through herd management areas and other areas containing sensitive biological resources, adverse impacts to those resources would be small because the heavy-haul trucks would use existing roads and would represent a very small percentage of the traffic along those roads. [See DIRS 156930-NDOT (2001, all) for traffic counts along Nevada highways.] As with heavy-haul trucks, legal-weight truck shipments that used existing highways would cause only very small impacts to biological resources.

For highway upgrades, DOE or the State of Nevada would reduce concerns about soil contamination or erosion by incorporating appropriate mitigation measures during construction. These measures would include the proper control of hazardous materials and use of dust suppression and other control techniques to reduce erosion. As a result, the implementing alternatives for transportation in Nevada would be unlikely to have impacts on soil. Impacts to biological resources and soils are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively.

6.1.2.5 Cultural Resources

A comprehensive review of existing literature and many discussions with responsible Federal and State of Nevada agencies and Native American groups has identified many archaeological and cultural sites and features. Pertinent information is presented in Chapter 3, Sections 3.1.6, 3.2.2.1.5, and 3.2.2.2.5. Much of the information has been confirmed and additional information acquired during field observations.

Based on this extensive review of available information and recent field observations, the construction and operation of a branch rail line in any of the candidate corridors could present the potential for direct or indirect impacts (such as crushing or disturbing of sites; soil erosion exposing or covering sites) to archaeological and historic resources, including those related to Native American culture. None of the five rail corridors passes through presently established reservation lands, but the Bonnie Claire Alternate (for either the Carlin or Caliente Corridor) passes directly through the recently established Timbisha Shoshone Trust Lands at Scottys Junction. In some cases, proposed corridors cross historic linear sites (such as the Pony Express Trail) (see Chapter 3, Section 3.2.2.1.5). In these cases potential impacts could be identified during field studies that would evaluate the current condition of the resources at particular locales, the overall character of the impacts, and the effort required to mitigate the impacts. If a rail corridor was selected, DOE would conduct additional archaeological surveys and ethnographic studies as part of additional National Environmental Policy Act reviews to determine potential impacts of alternative alignments within a corridor.

The determination of the potential for impacts to archaeological resources and Native American cultural values from the upgrading and use of existing Nevada highways for heavy-haul truck shipments could require study. Although the widening of roadways and development of turnouts would occur within existing rights-of-way, disturbance of cultural resources near the roadway and, in some cases, within existing rights-of-way could occur. The American Indian Writers Subgroup has commented that ethnographic field studies will be needed to determine specific potential impacts to Native American cultural properties and values for candidate rail corridors (DIRS 102043-AIWS 1998, p. 4-6).

6.1.2.6 Occupational and Public Health and Safety

Impacts to occupational and public health and safety include industrial safety impacts to workers from construction and operations, radiological impacts to workers and the general public from external radiation exposure and exposure to vehicle emissions during normal operations and incident-free transportation, radiological impacts from transportation accident scenarios, radiological impacts from hypothetical severe accident scenarios that would breach shipping casks, and impacts from traffic accidents.

Potential industrial safety impacts to workers from construction and operations are listed in Table 6-3. Estimated impacts from industrial accidents would be higher for rail than for heavy-haul trucks, but in all cases there would be less than 1 industrial safety-related fatality during construction for any of the five branch rail line or five heavy-haul truck implementing alternatives. No industrial safety-related fatalities would be expected to occur during operations.

Table 6-3. Industrial safety impacts to workers from construction and operation of Nevada transportation implementing alternatives.[a]

Impact	Branch rail line				
	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Total recordable cases	220	210	180	150	110
Lost workday cases	110	110	95	76	58
Fatalities (industrial accidents)	0.4	0.4	0.4	0.3	0.2
	Heavy-haul truck[b]				
	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake
Total recordable cases	370	320	330	210	210
Lost workday cases	190	170	180	110	110
Fatalities (industrial accidents)	0.9	0.8	0.8	0.5	0.5

a. Impacts are totals for 24 years of operations. There are no impacts for the legal-weight truck scenario.
b. Includes impacts to workers at an intermodal transfer station.

Potential radiological impacts and vehicle emissions-related impacts from normal operations and incident-free transportation in Nevada for each of the rail and heavy-haul truck implementing alternatives and for the mostly legal-weight truck scenario are presented in Table 6-4. Radiological impacts to members of the public from external radiation exposure and risks from exposure to vehicle emissions during incident-free transportation would be lowest for rail, intermediate for heavy-haul trucks, and highest for legal-weight truck transportation, where an estimated 0.3 latent cancer fatalities could occur over 24 years. Impacts from vehicle emissions would be low in all cases (0.001 or fewer fatalities).

Table 6-4. Worker and public health and safety impacts from Nevada transportation implementing alternatives.[a]

Impact	Legal-weight truck[b]	Branch rail line: Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Workers						
Maximally exposed individual probability of LCF[c]	0.02	0.02	0.02	0.02	0.02	0.02
Worker population LCFs	0.75	0.34	0.39	0.3	0.3	0.28
Public						
Maximally exposed individual probability of LCF	0.0016	0.00015	0.00015	0.00015	0.00015	0.00015
General population LCFs	0.17	0.009	0.019	0.009	0.08	0.013
Vehicle emissions-related health effects (fatalities)	0.09	0.25	0.25	0.2	0.23	0.13
Accident risk[d]						
Population LCFs	0.000026	0.000001	0.000001	0.000001	0.000004	0.000001
Maximum reasonably foreseeable accident scenario						
Population LCFs	0.5	5	5	5	5	5
Maximally exposed individual probability of LCF	0.0015	0.02	0.02	0.02	0.02	0.02
Traffic accident fatalities	0.49	1.93	1.85	1.57	1.27	0.94

Impact	Heavy-haul truck[b]: Caliente	Caliente-Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake
Workers					
Maximally exposed individual probability of LCF[c]	0.02	0.02	0.02	0.02	0.02
Worker population LCFs	0.76	0.61	0.66	0.59	0.57
Public					
Maximally exposed individual probability of LCF	0.00016	0.00016	0.00016	0.00016	0.00016
General population LCFs	0.04	0.03	0.11	0.17	0.08
Vehicle emissions-related health effects (fatalities)	0.47	0.32	0.46	0.42	0.29
Accident risk[d]					
Population LCFs	0.000005	0.000001	0.000028	0.00006	0.000028
Maximum reasonably foreseeable accident scenario					
Population LCFs	5	5	5	5	5
Maximally exposed individual probability of LCF	0.02	0.02	0.02	0.02	0.02
Traffic accident fatalities	4.1	2.76	3.47	1.98	1.93

a. Impacts are totals for 24 years of operations.
b. Includes impacts to workers at an intermodal transfer station.
c. LCF = latent cancer fatality.
d. In this table, radiological accident dose risk is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. This sum is converted to latent cancer fatalities using the conversion factor of 0.0005 latent cancer fatality per person-rem.

The overall radiological accident risk from all accidents over the 24 years of transportation activities in Nevada would be no higher than about 0.003 latent cancer fatality in the potentially exposed population within 80 kilometers (50 miles). Accident risk would be highest for the heavy-haul implementing alternatives and lower for the mostly legal-weight truck scenario and rail implementing alternatives. The Jean rail and Sloan/Jean heavy-haul truck implementing alternatives would have higher accident risks than other implementing alternatives. The estimated accident risks are presented in Table 6-4.

The Nuclear Regulatory Commission published a draft Addendum 1 (DIRS 148185-NRC 1999, all) to NUREG-1437, Volume 1, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (DIRS 101899-NRC 1996, all) to provide a technical basis to amend Commission regulations with the objective of improving the efficiency of renewing nuclear plant operating licenses well-understood environmental impacts to avoid repetitive reviews. The addendum addresses two aspects of spent nuclear fuel transportation that the original Commission analysis did not address—the cumulative impacts of transportation of commercial spent nuclear fuel in the vicinity of the proposed repository at Yucca Mountain, and the impacts of transporting higher-burnup fuel. The results of this DOE EIS analysis appear to be consistent with the Nuclear Regulatory Commission conclusion in the addendum, which is that "radiological and accident risks of SNF [spent nuclear fuel] transport in the vicinity of Las Vegas are within regulatory limits and small."

6.1.2.7 Socioeconomics

Socioeconomic impacts of transportation (changes in the level of employment, population, real disposable income, Gross Regional Product, and State of Nevada and local government expenditures) would occur from the construction and operation of a branch rail line, from upgrading a heavy-haul truck route, from transporting large shipping casks using heavy-haul trucks, and from constructing and operating an intermodal transfer station. Figures 6-5 through 6-8 show total regional employment changes in the peak year of construction, and average total employment in the region of influence from operations activities. Because of the large population and employment in the socioeconomic region of influence (principally in Clark County), impacts from construction activities would generally be less than 3 percent of the baseline for each socioeconomic measure in all three counties in the region of influence, for the rail or heavy-haul truck implementing alternatives. Changes in Lincoln County (the two rail corridors and three routes for heavy-haul trucks originating in Caliente) would be more visible, but still generally less than 3 percent of the applicable baseline and would not be greater than historic short-term socioeconomic changes in the county over the past two decades. The operational period for either a branch rail line or a heavy-haul truck route probably would generate relatively constant employment levels. Changes to the baseline regional populations and employment from construction or operation of a rail or heavy-haul truck implementing alternative would be unlikely to have consequences greater than 3 percent of the population baseline. DOE anticipates that the changes in the economic measures of Gross Regional Product, real disposable income, and State of Nevada and local government expenditures would be less than 3 percent of the baselines in each county. Changes in employment and subsequent changes in population would be the principal cause of the changes in these measures. Figures 6-5 through 6-8 show the changes in employment and population expected during construction and operations if DOE implemented one of the five rail or five heavy-haul truck implementing alternatives.

DOE performed detailed analyses for the corridors of the five branch rail line implementing alternatives and the five heavy-haul truck implementing alternatives. The results of these analyses, which are driven by the length of the rail corridors or the cost of construction and upgrades for the proposed routes for heavy-haul trucks, are representative of the variations (options and alternates) of each corridor listed in Appendix J, Section J.3.1.2. The lengths of the variations for each corridor are similar, as listed in Section 6.3.2.2.

In light of public comments received on the Draft EIS concerning perception-based and stigma-related impacts, DOE examined relevant studies and literature on perceived risk and stigmatization of communities to determine whether the state of the science in predicting future behavior based on perceptions had advanced sufficiently since scoping to allow DOE to quantify the impact of public risk perception on economic development or property values in potentially affected communities. Of particular interest were those scientific and social studies carried out in the past few years that directly relate to either Yucca Mountain or to DOE actions such as the transportation of foreign research reactor spent nuclear fuel. DOE also reevaluated the conclusions of previous literature reviews such as those

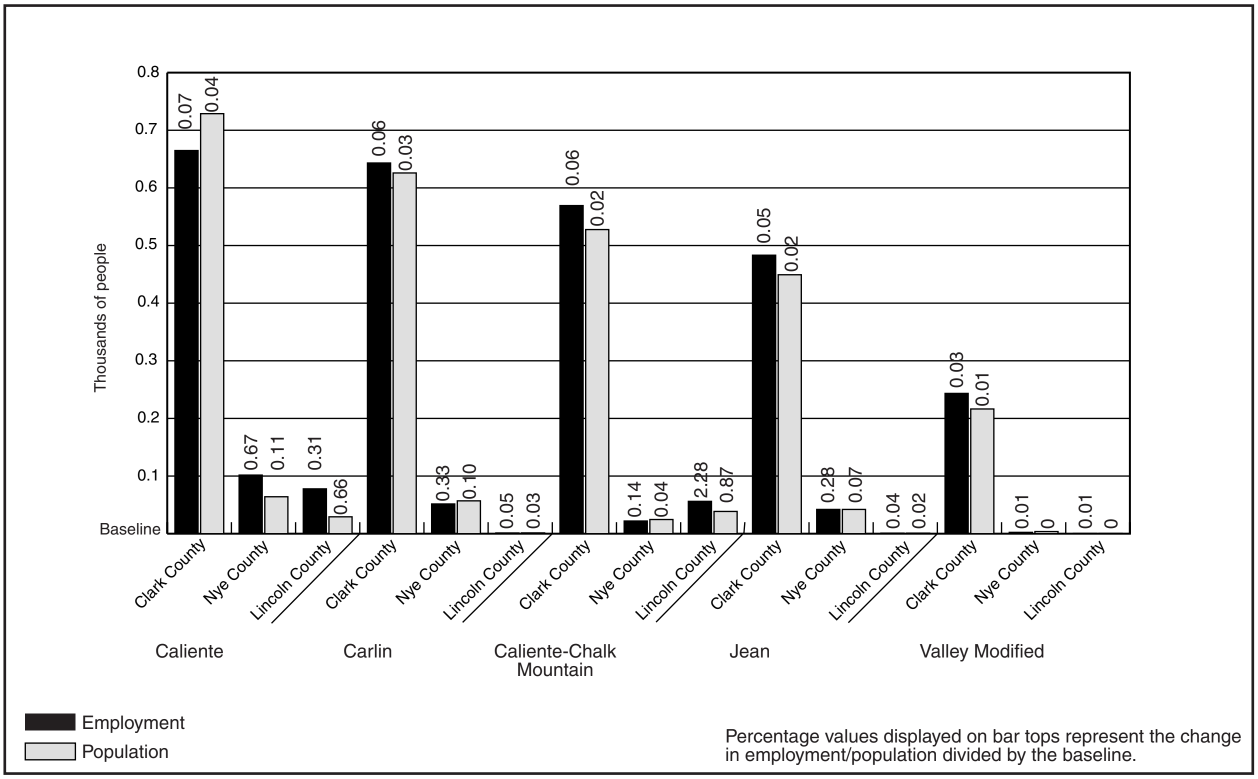

Figure 6-5. Population and employment for branch rail line implementing alternatives, construction (peak years).

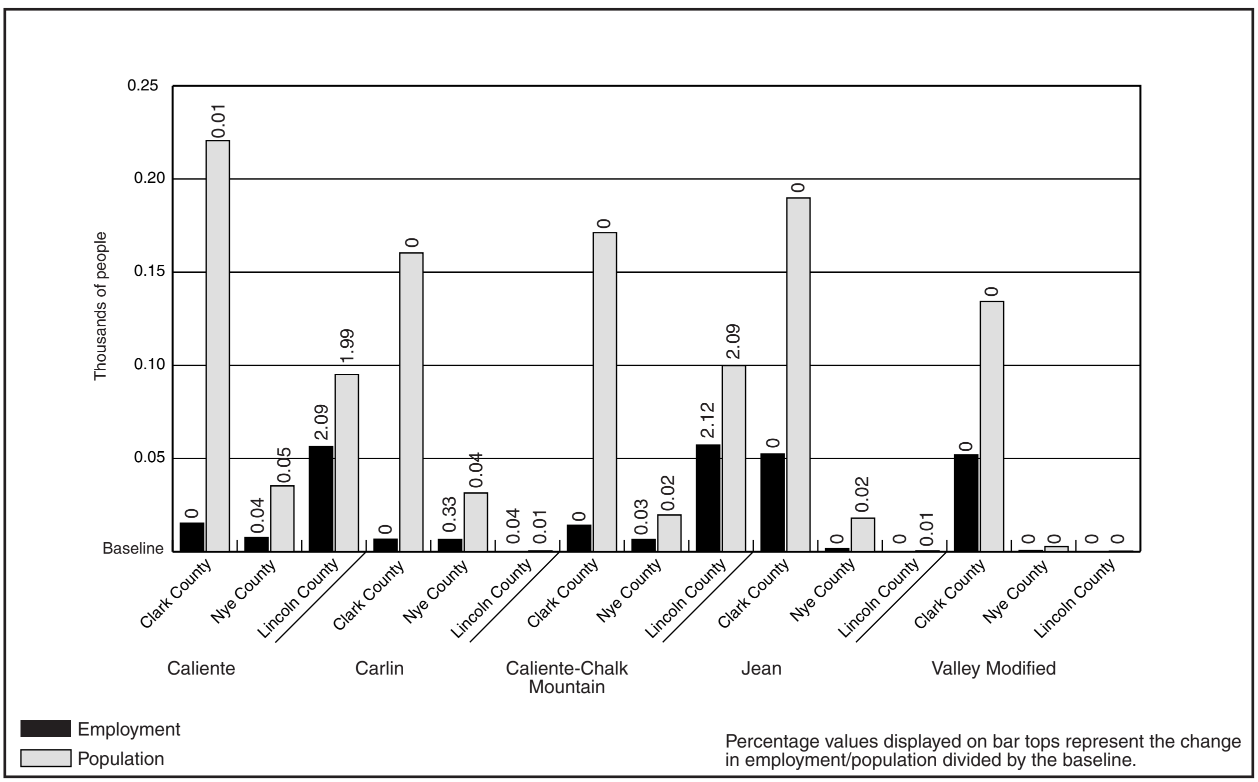

Figure 6-6. Population and employment for branch rail line implementing alternatives, operations (average years).

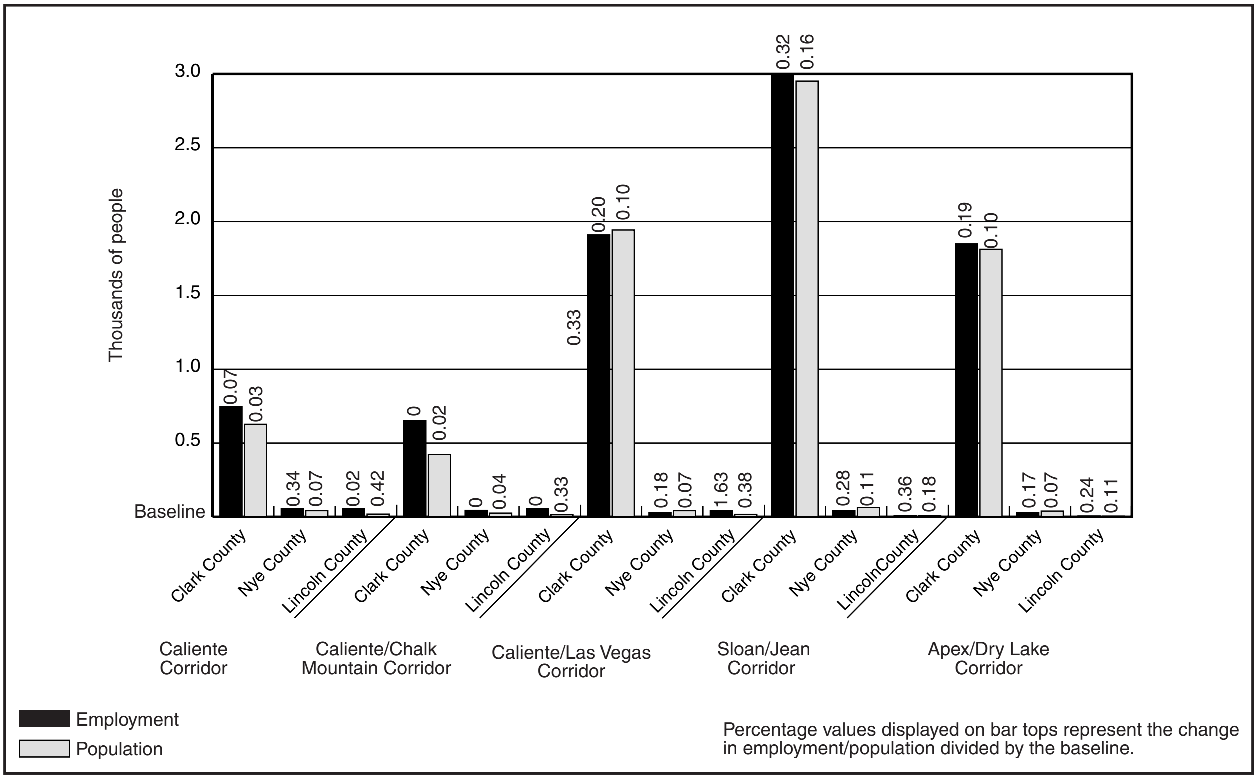

Figure 6-7. Population and employment for heavy-haul implementing alternatives, construction (peak years).

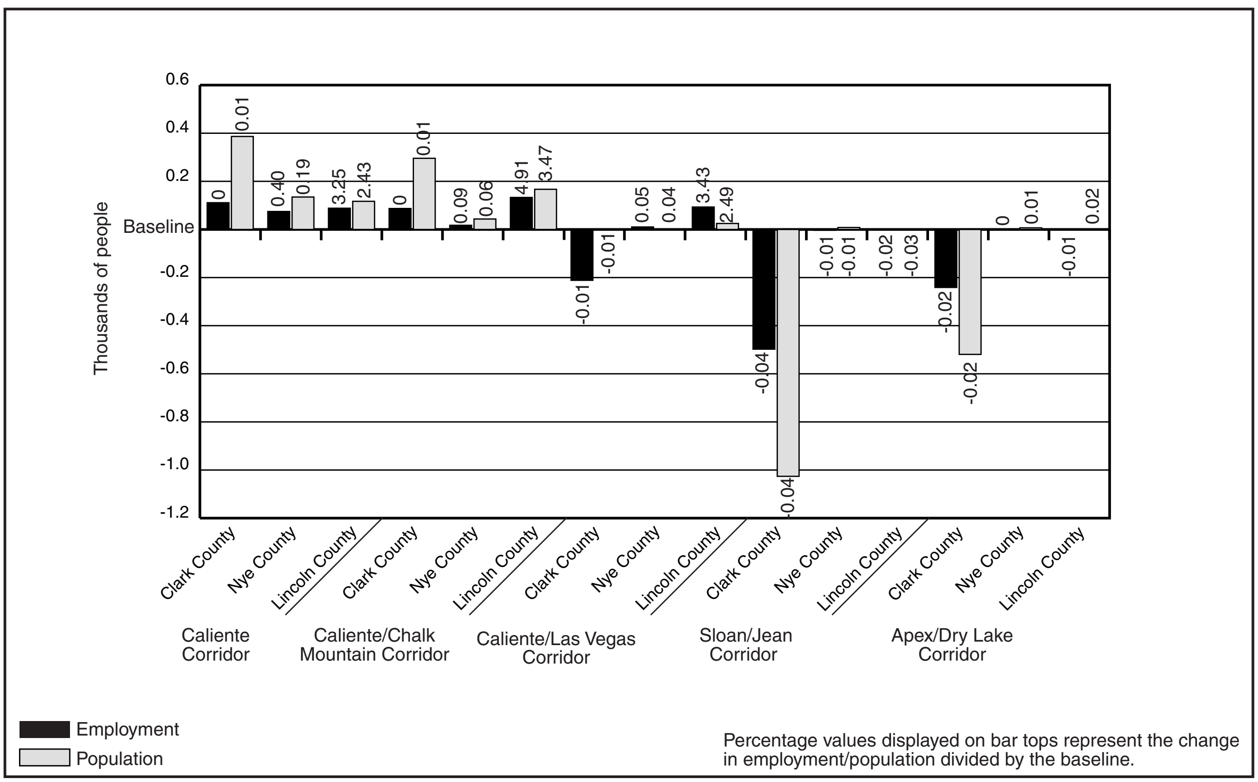

Figure 6-8. Population and employment for heavy-haul implementing alternatives, operations (average years).

conducted by the Nuclear Waste Technical Review Board and the State of Nevada, among others. DOE has concluded that:

- While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable methods whereby such impacts could be predicted with any degree of certainty
- Much of the uncertainty is irreducible, and
- Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

While stigmatization of southern Nevada can be envisioned under some scenarios, it is not inevitable or numerically predictable. Any such stigmatization would likely be an aftereffect of unpredictable future events, such as serious accidents, which may not occur. As a consequence, DOE did not attempt to quantify any potential for impacts from risk perceptions or stigma in this Final EIS. Chapter 2, Section 2.5.4 contains further detail.

6.1.2.8 Noise and Vibration

Noise from the construction of a branch rail line or upgrades to highways for heavy-haul trucks would be transient and not excessive. In addition, noise from trains, which would occur during as many as five weekly round trips, would not be excessively disruptive. Heavy-haul truck operations would use existing highways that already have traffic, including semi-trailer trucks. The American Indian Writers Subgroup identified noise from transportation as a concern because of its effects on ceremonies and the solitude necessary for healing and praying (DIRS 102043-AIWS 1998, all).

Construction upgrades of heavy-haul truck routes and construction of branch rail lines would be unlikely to cause vibration damage to historic buildings because of the distance of potentially sensitive buildings from construction sites. Upgrading of roads where they pass through or near communities would have the most potential for noise or vibration to affect buildings or be a nuisance to residents.

Train Operations. Ground vibration from trains using a branch rail line in Nevada to transport spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be well below levels that would contribute to damage to historic buildings or structures.

Because DOE would place the candidate branch rail lines in areas away from communities, and because development and construction and most operations would occur during daylight hours, the potential for noise or vibration impacts from rail line construction and operation is low.

Heavy-Haul Truck Operation. Because they would use air-filled rubber tires with loads distributed to over 100 wheels and would operate on improved roadways having compacted foundation soils, ground vibration from heavy-haul trucks would be much less than that from trains. In addition, DOE assumes that speeds near communities with sensitive historic structures and buildings would be limited for safety, further ensuring that vibration criteria were not exceeded.

6.1.2.9 Aesthetics

Four of the five candidate rail corridors would not have large or lasting aesthetic impacts. The upgrades of existing highways would present short-term aesthetic impacts during construction but these would be temporary and transient, resulting largely from widening the highways. Routes originating in Caliente could cause impacts on the Class II lands of Kershaw Ryan State Park, the entrance of which is on the east side of the Meadow Valley Wash across from a potential location for an intermodal transfer station. However, the character of this area of the Meadow Valley Wash has been modified by the Union Pacific rail line, the City of Caliente water treatment facility, and agricultural uses of lands in the vicinity. Studies have identified a potential visual resource impact for the northeastern portion of the Jean Corridor that passes through the Spring Mountains. The character of Class II lands (defined in Chapter 3, Section 3.1.10) in that part of the corridor would change, possibly in conflict with visual resource management goals. All routes for heavy-haul trucks and all branch rail lines except Carlin would pass through Class III lands. Aesthetic conditions would not be affected by legal-weight trucks on existing, well-traveled highways.

6.1.2.10 Utilities, Energy, and Materials

Impacts to utility, energy, and material resources from the construction and operation of any of the rail or heavy-haul truck implementing alternatives would be small compared to usage in Nevada. For example, Nevada fossil-fuel consumption during 1996 was about 3.8 billion liters (1 billion gallons) (DIRS 148081-BTS 1999, Table MF-21). By comparison, the largest fossil-fuel use for any of the implementing alternatives would be less than 50 million liters (13 million gallons) over the construction period, or less than 0.5 percent of the Nevada annual use. Similarly, concrete use for the largest implementing alternative would be about 460,000 metric tons (200,000 cubic meters), also less than 2 percent of the Nevada annual use of 7.4 million metric tons (3.2 million cubic meters) (DIRS 104926-Bauhaus 1998, all). Figures 6-9 and 6-10 compare the use of resources for construction of the rail and heavy-haul truck implementing alternatives, respectively.

6.1.2.11 Wastes

Construction and operation of a branch rail line or use of heavy-haul trucks would produce small amounts of construction debris, sanitary solid waste, and sanitary wastewater and possibly a small amount of hazardous waste. Under the heavy-haul truck alternative, a small amount of low-level radioactive waste could be generated at an intermodal transfer station. Nonradioactive wastes would be recovered for recycling, placed in permitted landfills, reused, or in the case of sanitary sewage, treated and disposed of on the site. All waste would be managed in accordance with applicable environmental, occupational safety, and public health and safety requirements to minimize the possibility of adverse impacts to animals, vegetation, air quality, soil, and water resources.

There would be minimal impacts on the capacity of facilities to treat or dispose of wastes from Nevada transportation. For example, branch rail line construction camps with running water would generate about 37 million liters (10 million gallons) of sanitary sewage that could be treated and disposed of in permitted septic systems and about 940 metric tons (1,000 tons) of sanitary solid waste during the peak year of employment. For comparison, the waste volume from Nevada transportation would be small in relation to the volumes disposed of in the State in 2000 [3.5 million metric tons (3.9 million tons) of sanitary solid waste] (DIRS 155565-NDEP 2001, Section 2.1), so the rail construction camps would add about 0.027 percent. The estimated construction debris from an intermodal transfer station would be 23 metric tons (26 tons). Approximately 750,000 metric tons (820,000 tons) of construction debris was disposed of in Nevada in 2000 (DIRS 155565-NDEP 2001, Section 2.1), so the construction of an intermodal transfer station would add less than approximately 0.01 percent to the total. About 1,400 kilograms (3,000 pounds) of tires and drained oil filters (industrial and special wastes) would be generated during truck maintenance activities at an intermodal transfer station. About 83,000 metric tons (91,000 tons) of this type of waste was disposed of in Nevada in 2000 (DIRS 155565-NDEP 2001, Section 2.1), so the truck maintenance waste would add less than about 0.01 percent. Hazardous and low-level radioactive waste would have a small impact on the ability of facilities to treat and dispose of the waste. According to the Environmental Protection Agency, treatment and disposal capacity in the western states for hazardous waste would be above the expected demand (by 7 times for incineration and

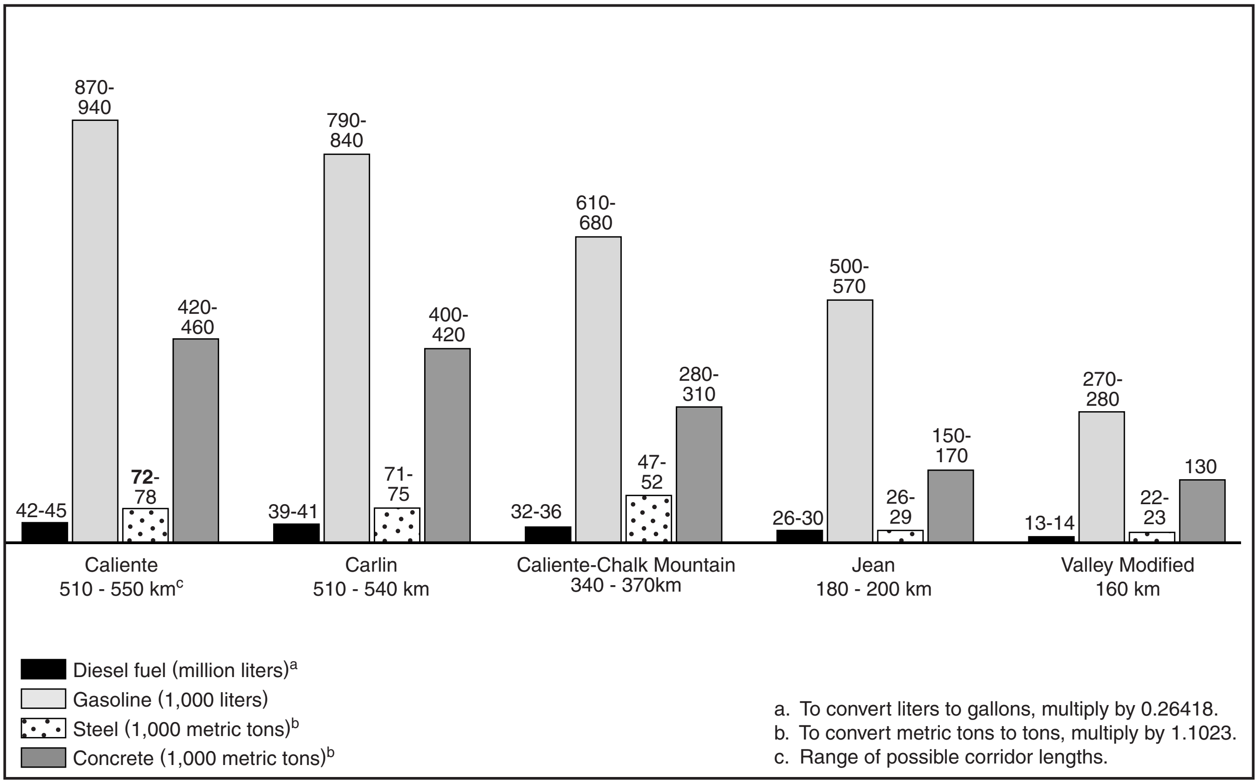

Figure 6-9. Utility, energy, and material use for construction of a branch rail line in Nevada.

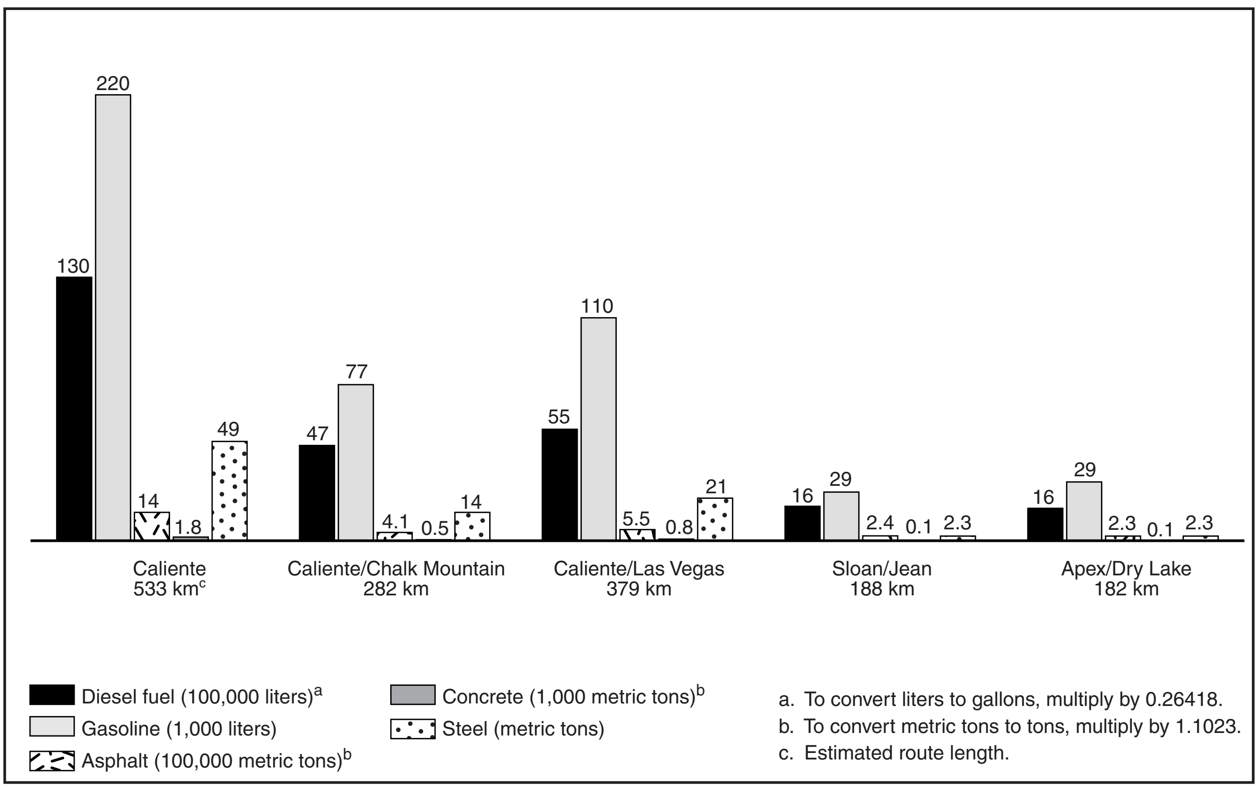

Figure 6-10. Utility, energy, and material use for upgrading of Nevada highways for heavy-haul truck use.

50 times for landfill) until 2013 (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50). Disposal capacity for a broad range of low-level radioactive wastes would be available at two currently licensed facilities (DIRS 152583-NRC 2000, section on U.S. Low-level Radioactive Waste Disposal).

6.1.2.12 Environmental Justice

Section 6.3 discusses the methods used in the analysis of potential environmental justice concerns. No potentially disproportionately high and adverse impacts to minority or low-income populations were identified in areas of land use; air quality; hydrology; biological resources and soils; socioeconomics; aesthetics; and occupational and public health and safety for construction or operations under the mostly legal-weight truck scenario in Nevada or any of the 10 rail and heavy-haul truck transportation implementing alternatives. Potential visual resource (aesthetic) impacts were identified for the Jean Corridor but these were not determined to be disproportionate. However, no potentially disproportionately high and adverse impacts would occur in these areas for legal-weight truck transportation that would use existing highways. If DOE identified potentially high and adverse impacts for a corridor or route, it would mitigate them (as discussed in Chapter 9).

Because impacts to humans and other impacts that could affect minority or low-income populations or populations of American Indians would not be disproportionately high and adverse, including mitigation as needed, an additional environmental justice analysis is not required. Chapter 4, Section 4.1.13.4, contains an environmental justice discussion of a Native American perspective on the Proposed Action.

6.1.3 TRANSPORTATION OF OTHER MATERIALS AND PERSONNEL

Other types of transportation activities associated with the Proposed Action would involve the transportation of personnel and of materials other than the spent nuclear fuel and high-level radioactive waste discussed above. These other materials include construction materials and consumables for repository construction and operation, including repository components (for example, disposal containers, drip shields, etc.); waste including low-level waste, construction and demolition debris, sanitary and industrial solid waste, and hazardous waste; and office and laboratory supplies, mail, and laboratory samples.

The quantities of construction materials, consumables, site-generated waste, laboratory samples, and supplies, would differ for the range of repository operating modes. The number of commuting employees would also differ. Therefore, the transportation impacts listed in Table 6-5 are ranges, from the least to the greatest impact. Appendix J, Section J.3.6, provides additional detail.

Table 6-5. Impacts related to repository transportation activities.

Factor	Impact
Total kilometers traveled (millions)	610 - 1,100
Total nonradiological latent fatalities[a]	0.9 - 1.6
Total nonradiological traffic fatalities[b]	6.3 - 11.4
Total nonradiological commuting worker traffic fatalities	2.4 - 4.2

a. From commuter and materials transportation.
b. From materials transportation and public fatalities from commuter transportation.

Additional traffic in the Las Vegas air basin would result in emissions of carbon monoxide, most significantly during the repository phases of construction and operation and monitoring. The Las Vegas air basin is in nonattainment status for carbon monoxide, which is largely a result of vehicle emissions (DIRS 156706-Clark County 2000, Appendix A, Table 1-3). As part of the conformity review DOE conducted using the guidance in DIRS 155566-DOE (2000, all), it was determined that the transportation of personnel, materials, and supplies through the Las Vegas air basin would not exceed the carbon monoxide General Conformity threshold level [91 metric tons (100 tons) per year; 40 CFR 93.153] for serious nonattainment status. The highest total emissions for personnel, materials, and supplies would be 50 tons per year during the construction phase and 67 tons per year during the operations and monitoring phase; emissions would contribute a maximum of an additional 0.07 percent to the estimated 2000 daily carbon-monoxide levels in the nonattainment area (DIRS 156706-Clark County 2000, Appendix A, Table 1-3).

Impacts in other environmental resource areas would be unlikely to occur.

6.2 National Transportation

This section describes the estimated national transportation impacts from shipping spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites throughout the United States to the proposed Yucca Mountain Repository. This section includes the following:

- Definition and an overview of the analysis scenarios (Section 6.2.1)
- Impacts to workers and the public from spent nuclear fuel and high-level radioactive waste loading operations at commercial and DOE sites (Section 6.2.2)
- Potential incident-free (routine) radiological impacts and vehicle emission impacts (Section 6.2.3)
- Potential accident scenario impacts (Section 6.2.4).

National transportation of spent nuclear fuel and high-level radioactive waste, which would use existing highways and railroads, would average 7.8 million truck kilometers (4.9 million miles) per year for the mostly truck case and 1.6 million railcar kilometers (1 million miles) per year for the mostly rail case. Barges used to ship rail casks to nearby railheads from commercial sites not served by a railroad could average as much as 6,500 kilometers (4,000 miles) per year. The national yearly average for total highway and railroad traffic is 186 billion truck kilometers (116 billion miles) and 49 billion railcar kilometers (30 billion miles) (DIRS 150989-BTS 1998, pp. 5 and 6)]. Spent nuclear fuel and high-level radioactive waste transportation would represent a very small fraction of the total national highway and railroad traffic (0.004 percent of truck kilometers and 0.003 percent of railcar kilometers). Domestic waterborne trade in 1995 accounted for about 1 billion metric tons (910 million tons) (DIRS 148158-MARAD 1998, all). This represents about 1 million barge shipments per year. Thus, shipments of spent nuclear fuel by barge would only be a very small fraction of the total annual domestic waterborne commerce.

With the exception of occupational and public health and safety impacts, which are evaluated in this section, the environmental impacts of this small fraction of all national transportation would be very small in comparison to the impacts of other nationwide transportation activities. Thus, the national transportation of spent nuclear fuel and high-level radioactive waste would have very small impacts on land use and ownership; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; or waste management.

To determine if pollutants of concern from national transportation vehicles (truck and rail) would degrade air quality in nonattainment areas, DOE reviewed traffic volumes in these areas. This review determined that the numbers of shipments of Yucca Mountain-destined vehicles through these areas would be very small in relation to normal traffic volumes. Therefore, the impact to air quality in these areas, except Nevada (see Section 6.1.3), would be very small.

Radiological impacts of accidents on biological resources would be extremely unlikely. The analysis focused the impacts from accidents on human health and safety. A severe accident scenario, such as the maximum reasonably foreseeable accident scenarios discussed in Section 6.2.4.2, that would cause a release of contaminated materials would be very unlikely. The probabilities of the severe accident scenarios discussed in Section 6.2.4.2 are less than 3 in 10 million per year for both the mostly legal-weight truck and mostly rail transportation scenarios. Because of the low probability of occurrence, an accident scenario during the transport of spent nuclear fuel and high-level radioactive waste would be unlikely to cause adverse impacts to any endangered or threatened species, and impacts to other plants and animals would be small. Therefore, the analysis did not evaluate the impacts for these environmental parameters for national transportation activities further.

This chapter does not evaluate the risks of economic loss or resultant environmental consequences from potential transportation accidents that could cause releases of radioactive materials. DOE did not perform these analyses because estimating economic risks and environmental consequences would depend on many factors associated with accidents that cannot be known in advance. Therefore, the information that would be needed for such an analysis is not available. Section J.1.4.2.5 of Appendix J presents a review and analysis of studies by the U.S. Nuclear Regulatory Commission, the National Aeronautics and Space Administration, DOE, and others that discusses cost factors and provides estimates of the range of costs and environmental consequences of cleaning up contamination following hypothetical accidental releases of radioactive materials.

6.2.1 ANALYSIS SCENARIOS AND METHODS

Under the mostly legal-weight truck scenario for national transportation, DOE would transport shipments (with the exception of naval spent nuclear fuel and possibly some DOE high-level radioactive waste) by legal-weight truck to Nevada. Naval spent nuclear fuel would be shipped by rail from the Idaho National Engineering and Environmental Laboratory. Under the mostly-legal weight truck scenario, DOE assumed that some shipments of DOE high-level radioactive waste would use *overweight trucks*. With the exception of permit requirements and operating restrictions, the vehicles for these shipments would be similar to legal-weight truck shipments but might weigh as much as 52,200 kilograms (115,000 pounds). States routinely issue special permits for trucks weighing up to 58,500 kilograms (129,000 pounds).

Figure 6-11 shows the highway routes (mostly Interstate Highways) that the analysis used to estimate transportation-related impacts, along with the locations of the commercial and DOE sites and Yucca Mountain. The routes selected for analysis are representative of routes that DOE could use for truck shipments if the Yucca Mountain site was approved. In addition, the highway routes shown would conform to the routing requirements in 40 CFR 397.101 (see Appendix J, Section J.1.2).

Although DOE cannot be certain of the actual mix of rail and truck shipments that would occur, it expects that the mostly rail scenario best represents the mix of modes it would use. This belief is based on analyses the Department has done to assess generator site capabilities to handle larger (rail) casks, distances to suitable railheads, and historic experience in actual shipments of fuel, waste, or large reactor-related components. In addition, DOE considered relevant information published by knowledgeable sources such as the Nuclear Energy Institute, which provided information on capabilities of generator sites to handle large rail casks (DIRS 155777-McCullom 2000). Although DOE believes the mostly rail scenario best represents what would be likely for the transportation of spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository, Appendix J, Section J.1.2.1.4 describes an analysis that illustrates how changes in the mix of rail and truck modes would change estimated health and safety impacts for national transportation. The results of the analysis indicated how a mix between the limits represented by the mostly legal-weight truck and mostly rail scenarios would result in health and safety impacts that would be between those estimated for the two scenarios and would not be greater than the impacts from either scenario.

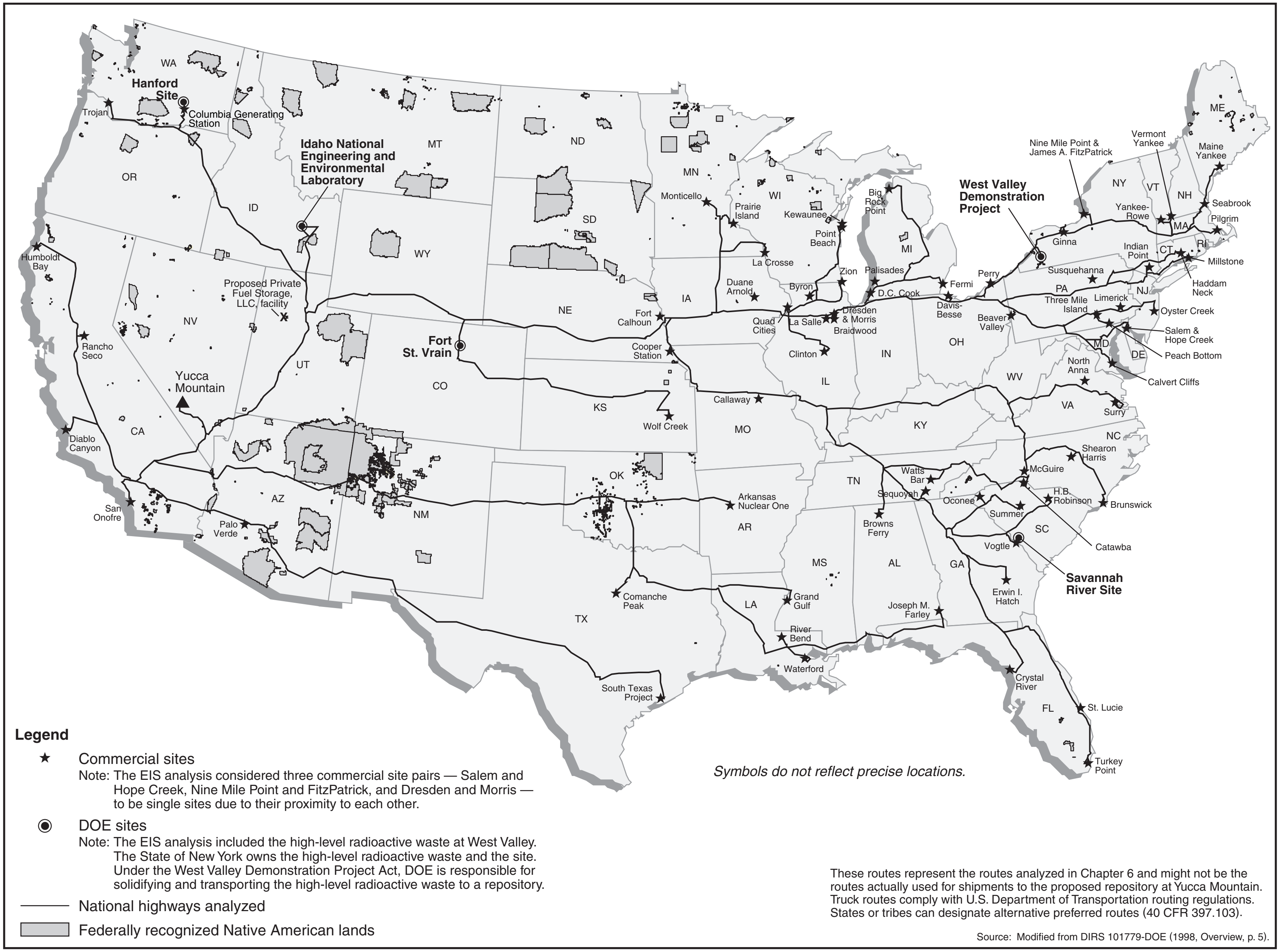

Figure 6-11. Representative truck routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

MOSTLY LEGAL-WEIGHT TRUCK AND MOSTLY RAIL SCENARIOS

The Department would prefer most shipments to a Yucca Mountain repository be made using rail transportation. It also expects that the mostly rail scenario described in this EIS best represents the mix of rail and truck transportation that would be used. However, it cannot be certain of the actual mix of rail and truck transportation that would occur over the 24 years of the Proposed Action. Consequently, DOE used the mostly legal-weight truck and mostly rail scenarios as a basis for the analysis of potential impacts to ensure the analysis addressed the range of possible transportation impacts. The estimated number of shipments for the mostly legal-weight truck and mostly rail scenarios represents the two extremes in the possible mix of transportation modes, thereby covering the range of potential impacts to human health and safety and to the environment for the transportation modes DOE could use for the Proposed Action.

Under the national transportation mostly rail scenario, DOE would transport shipments (with the exception of commercial spent nuclear fuel at six sites that do not have the capability to load a rail cask) by rail to Nevada. In addition, this scenario assumes that 24 commercial sites that have the capability to handle and load rail casks, but that do not have railroad service, would make shipments to nearby railheads by barge or heavy-haul truck. Barge shipments of rail casks containing spent nuclear fuel could be possible from 17 commercial sites that are on or near navigable waterways. Figure 6-12 shows the railroad routes that the analysis used to estimate transportation-related impacts, along with the locations of the commercial and DOE sites and Yucca Mountain. The routes selected for analysis are representative of routes that could be used for rail shipments if the Yucca Mountain site was approved. The analysis estimated that these routes would most closely follow current railroad industry practices and the system-wide capability to ship hazardous materials safely. These routes would reduce time in transit, reduce the number of interchanges between railroads, and use mainline tracks to the maximum practical extent.

The railroad routes shown in Figure 6-12 could also be used by generators to transport spent nuclear fuel to a proposed Private Fuel Storage facility near Skull Valley in northwestern Utah (DIRS 152001-NRC 2000, all). Rail routes from that facility to connections with potential branch rail lines or to an intermodal transfer station in Nevada would be essentially the same as the western sections of rail routes analyzed in this chapter. Thus, impacts presented in this chapter for five candidate routes for heavy-haul trucks and five candidate rail corridors in Nevada would be about the same whether shipments were directly from 72 commercial and 5 DOE generator sites to a Yucca Mountain Repository or from a Private Fuel Storage facility in Skull Valley, Utah. Chapter 8, Section 8.4, discusses potential cumulative impacts of transporting commercial spent nuclear fuel to a Private Fuel Storage facility and then to a Yucca Mountain Repository (see Appendix J, Section J.1.2).

This section evaluates radiological and nonradiological impacts to workers and the public from routine transportation operations and from accidents. DOE used a number of computer models and programs to estimate these impacts; Appendix J describes the analysis assumptions and models.

The CALVIN model (DIRS 155644-CRWMS M&O 1999, pp. 2 to 22) was used to estimate the number of shipments of commercial spent nuclear fuel for both the mostly legal-weight truck and mostly rail scenarios. The CALVIN program used commercial spent nuclear fuel inventories and characteristics from the *Report on the Status of the Final 1995 RW-859 Data Set* (DIRS 104848-CRWMS M&O 1996, all) and the *Calculation Method for the Projection of Future SNF Discharges* (DIRS 156305-CRWMS M&O 2001, all) (see Appendix A) to estimate the number of shipments. For DOE spent nuclear fuel and high-level radioactive waste, the analysis used inventories and characteristics for materials to be shipped under the Proposed Action that were reported by the DOE sites in 1998 (see Appendix A) to estimate the number of shipments. Chapter 2, Section 2.1.3, and Appendix J discuss the number of shipments.

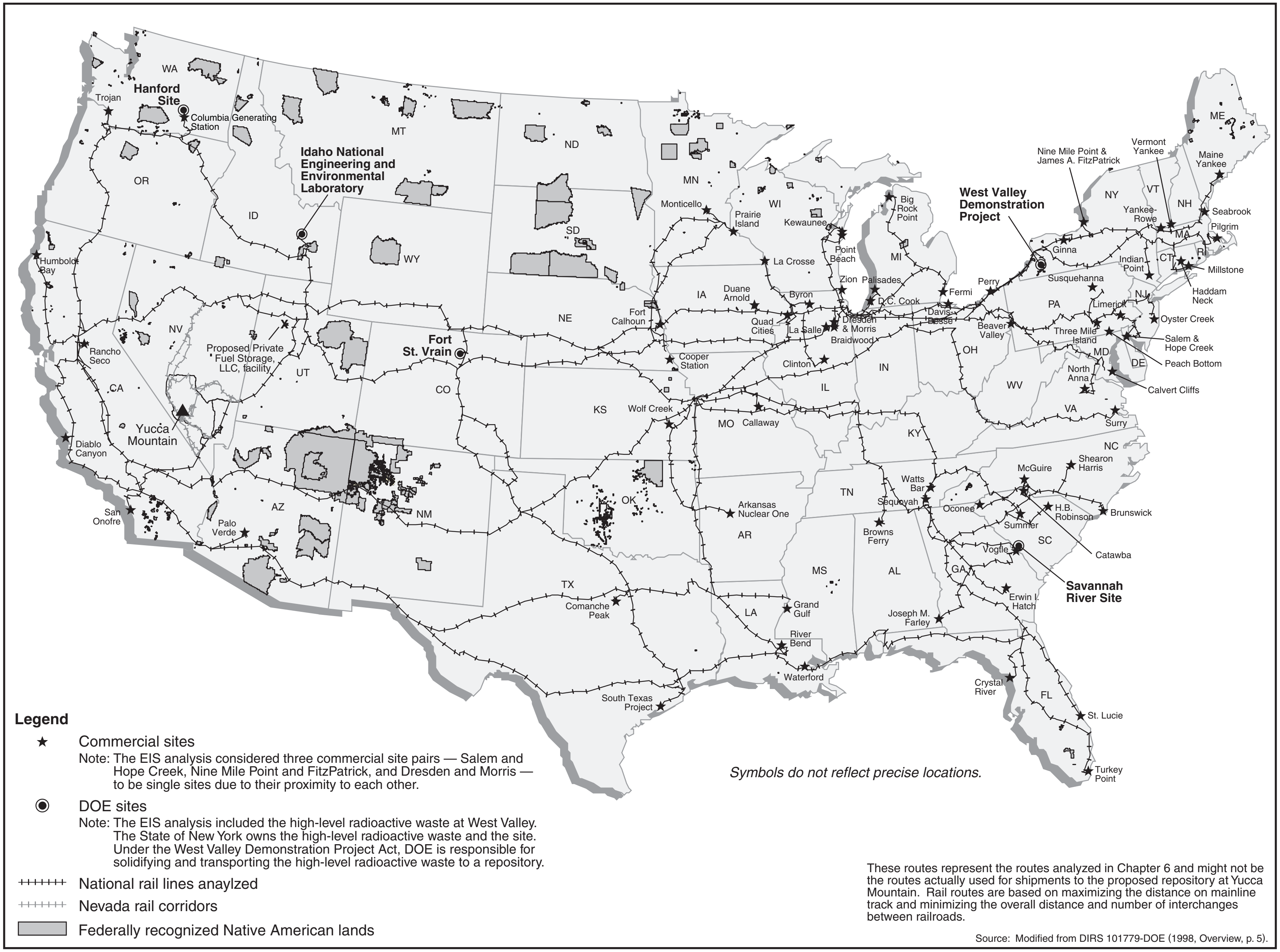

Figure 6-12. Representative rail routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

The transportation analyses used the following computer programs:

- HIGHWAY (DIRS 104780-Johnson et al. 1993, all) to identify the highway routes that it could use to transport spent nuclear fuel and high-level radioactive waste. All of the routes would satisfy U.S. Department of Transportation route selection regulations.
- INTERLINE (DIRS 104781-Johnson et al. 1993, all) to identify rail and barge routes for the analysis.
- RADTRAN 5 (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430 Neuhauser, Kanipe, and Weiner 2000, all) to estimate radiological dose risk to populations and transportation workers during routine operations. The analyses also used this program to estimate radiological dose risks to populations and transportation workers from accidents.
- RISKIND (DIRS 101483-Yuan et al. 1995, all) to estimate radiological doses to the maximally exposed individuals and to the population during routine transportation. This program also estimated radiological doses to the maximally exposed individuals and to the population from transportation accidents.

6.2.2 IMPACTS FROM LOADING OPERATIONS

This section describes potential impacts from loading spent nuclear fuel and high-level radioactive waste in transportation casks and on transportation vehicles at the 72 commercial and 5 DOE sites. It also describes methods for estimating radiological and industrial hazard impacts from routine loading operations and radiological impacts of loading accidents to workers and members of the public. During loading operations, radiological impacts to workers could occur from normal operations and accidents. In addition, workers could experience impacts from industrial hazards. Members of the public could experience radiological impacts if a loading accident occurred but would not experience impacts from industrial hazards, including hazards associated with nonradioactive hazardous materials. Nonradioactive hazardous materials would be used only in small quantities, if at all, in loading operations. Chapter 4 addresses impacts from unloading operations at the repository.

6.2.2.1 Radiological Impacts of Routine Operations

Radiological impacts to members of the public from routine operations would be very small. An earlier DOE analysis estimated that public dose from loading operations (primarily due to atmospheric effluents) would be less than 0.001 person-rem per metric ton of uranium loaded (DIRS 104731-DOE 1986, Volume 2, p. E.6) (see Appendix J for more information). Therefore, to be conservative this analysis estimated the dose to the public from loading operations by multiplying the value of 0.001 person-rem per metric ton of uranium by the 70,000 metric tons (77,000 tons) of spent nuclear fuel and high-level radioactive waste DOE would transport under the Proposed Action. [DIRS 104731-DOE (1986, Volume 2, all) uses the term “metric ton uranium,” which is essentially the same as metric tons of heavy metal for commercial spent nuclear fuel.] The resulting population dose would be 70 person-rem, which, based on conversion factors recommended by the International Commission on Radiological Protection, would result in 0.04 latent cancer fatality. The Commission recommends 0.0004 and 0.0005 latent cancer fatality per person-rem for involved worker populations and the general public, respectively (DIRS 101836-ICRP 1991, p. 22).

Table 6-6 lists estimated involved worker impacts from loading spent nuclear fuel at commercial sites and loading DOE spent nuclear fuel and high-level radioactive waste at DOE facilities for shipment to the Yucca Mountain site under the Proposed Action. The impacts assume worker rotation and other administrative actions at commercial sites would follow guidance similar to that in *DOE Standard - Radiological Control Manual* (DIRS 156764-DOE 1999, Article 211). Although the guidance that the annual dose received by an individual worker could be as high as 2 rem per year, DOE policy is to limit doses to individual workers to no more than 500 millirem per year. The maximum individual dose would be 12 rem over the 24 years of loading operations for individuals who worked the entire duration of repository operations. The estimated probability of a latent cancer fatality for an involved worker from this dose would be about 0.005 (5 chances in 1,000).

Table 6-6. Estimated radiological impacts to involved workers from loading operations.[a]

Impact	Mostly rail	Mostly legal-weight truck
Maximally exposed individual		
Dose (rem)	12[b]	12[b]
Probability of LCF[c]	0.005	0.005
Involved worker population[d]		
Dose (person-rem)	4,200	15,000
Number of LCFs	1.7	6.1

a. Numbers are rounded.
b. Based on 500-millirem-per-year administrative dose limit.
c. LCF = latent cancer fatality.
d. All involved workers at all facilities, preparing about 11,000 shipments under the mostly rail scenario and about 53,000 shipments under the mostly legal-weight truck scenario over 24 years.

As many as 2 latent cancer fatalities from the mostly rail scenario and about 6 latent cancer fatalities from the legal-weight truck scenario could result in the involved worker population over 24 years. The mostly legal-weight truck scenario would result in more potential impacts than the mostly rail scenario because of the increased exposure time needed to load more transportation casks.

To assess potential radiological impacts at generator facilities, the EIS analysis assumed that noninvolved workers would have no direct involvement with handling spent nuclear fuel or high-level radioactive waste. DOE expects radiological impacts to noninvolved workers to be even smaller than those to involved workers.

6.2.2.2 Impacts from Industrial Hazards

Table 6-7 lists estimated impacts to involved workers from industrial hazards over 24 years of loading operations at the 77 sites. Fatalities from industrial hazards would be unlikely from loading activities under either national transportation scenario. The mostly legal-weight truck scenario would have about three times the estimated number of total recordable cases and lost workday cases of the mostly rail scenario because there would be more shipments and more work time (full-time equivalent worker years). Using the assumption that the noninvolved workforce would be 25 percent of the number of involved workers, the analysis determined that impacts to noninvolved workers would be about 25 percent of those listed in Table 6-7.

Table 6-7. Impacts to involved workers[a] from industrial hazards during loading operations.[b]

Impact	Mostly rail	Mostly legal-weight truck
Total recordable cases[c]	130	380
Lost workday cases[d]	67	200
Fatalities[e]	0.29	0.9

a. Includes all involved workers at all facilities during 24 years of repository operations. During the 24 years of shipments to the proposed repository, these workers would put in 1,300 worker years (2,080 hours per worker year) preparing about 11,000 shipments under the mostly rail scenario and 3,700 worker years preparing about 53,000 legal-weight truck shipments and 300 naval spent nuclear fuel rail shipments under the mostly legal-weight truck scenario. Industrial safety impacts in the noninvolved workforce would be about 25 percent of those listed.
b. Numbers are rounded to two significant digits.
c. Total recordable cases (injury and illness) based on a 1998 loss incident rate of 0.08.
d. Lost workday cases based on a 1998 loss incident rate of 0.05.
e. Fatalities based on a 1998 loss incident rate of 0.000218.

To assess potential industrial safety impacts at generator facilities, the EIS analysis assumed that noninvolved workers would be persons with office-based administrative duties associated with loading operations. In addition to industrial safety impacts, traffic fatality and vehicle emissions impacts as a result of commuting workers associated with loading operations were estimated. Traffic involving commuting workers could result in 0.4 fatality under the mostly legal-weight truck scenario and 0.2 fatality under the mostly rail scenario. Estimated vehicle emissions impacts from commuting could result in 0.06 latent fatalities for the mostly legal-weight truck scenario and 0.02 for the mostly rail scenario.

6.2.3 NATIONAL TRANSPORTATION IMPACTS

The following sections discuss the impacts of transporting spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository under the mostly legal-weight truck and mostly rail scenarios. The analysis in this section addresses the impacts of incident-free transportation. Section 6.2.4 discusses accidents, and Appendix J contains the details of the analysis and its assumptions.

6.2.3.1 Impacts from Incident-Free Transportation – National Mostly Legal-Weight Truck Transportation Scenario

This section addresses radiological and nonradiological impacts to populations and maximally exposed individuals for incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly-legal weight truck scenario.

Incident-Free Radiological Impacts to Populations. Table 6-8 lists the incident-free population dose and latent cancer fatalities to workers and the public for the mostly legal-weight truck scenario. The impacts include those for the shipment of naval spent nuclear fuel by rail to Nevada, intermodal transfer of rail casks to heavy-haul trucks, and subsequent heavy-haul transportation to the proposed repository. Section 6.3.3 and Appendix J contain additional information on worker impacts from intermodal transfer operations. Worker impacts would include radiological exposures of security escorts for legal-weight truck, rail, and heavy-haul truck shipments and from the transfer of naval spent nuclear fuel shipments from rail to heavy-haul truck. The collective dose to the security escorts traveling in separate vehicles would be about 6 person-rem for legal-weight truck shipments. Doses to escorts of rail shipments of naval spent nuclear fuel, who would travel in railcars in sight of but separated from the cask cars, followed by escorted heavy-haul truck shipments in Nevada would be about 0.4 person-rem.

Table 6-8. Population doses and impacts from incident-free transportation for national mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Totals[d]
Involved workers			
Collective dose (person-rem)	14,000	29	14,000
Estimated LCFs[c]	5.6	0.01	5.6
Public			
Collective dose (person-rem)	5,000	20	5,000
Estimated LCFs	2.5	0.01	2.5

a. Impacts are totals for shipments over 24 years.
b. Includes impacts from intermodal transfer operations (see Section 6.3.3.1).
c. LCF = latent cancer fatality.
d. Totals might differ from sums of values due to rounding.

If escorts accompanied legal-weight truck shipments over the full length of their shipment routes, rather than only in highly populated urban areas as required by Federal regulations (10 CFR 73.37), the estimated doses to escorts over 24 years would be 360 person-rem (a 0.14 probability of a latent cancer fatality in the population of escorts).

In addition, as is recommended by the Commercial Vehicle Safety Alliance (DIRS 155863-CVSA 2000, all), the analysis assumed state safety inspections of shipments would occur only in originating and destination states. If inspections were conducted for every shipment in each state through which the shipment would pass, inspectors would receive an additional dose of 7,000 person-rem (about 2.8 latent cancer fatalities) over 24 years.

Appendix J, Section J.1.3.2.2.2 contains additional information about the analysis of impacts to escorts and inspectors.

The estimated radiological impacts would be 6 (5.6) latent cancer fatalities for workers and 3 (2.5) latent cancer fatalities for members of the public for the 24 years of operation. The population within 800 meters (0.5 mile) of routes would be about 10 million based on projections to 2035. About 2.3 million members of this population would be likely to incur fatal cancers from all other causes not associated with the Proposed Action (DIRS 153066-Murphy 2000, p. 5).

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-9 lists estimates of doses and radiological impacts for maximally exposed individuals for the legal-weight truck scenario (which considers drivers and security escorts). The risks are calculated for the 24 years of shipment activities. Appendix J discusses analysis methods and assumptions. State inspectors who conducted frequent inspections of shipments of spent nuclear fuel and high-level radioactive waste and transportation vehicle operating crews would receive the highest annual radiation doses.

Table 6-9. Estimated doses and radiological impacts to maximally exposed individuals for national mostly legal-weight truck scenario.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (including driver)	48[c]	0.02
Inspector	48[c]	0.02
Railyard crew member	0.13	0.00005
Public		
Resident along route	0.006	0.000003
Person in traffic jam	0.016[d]	0.000008
Person at service station	2.4[e]	0.0012
Resident near rail stop	0.009	0.000005

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operations.
c. Based on 2-rem-per-year administrative dose limit. If a lower dose limit, for example 500 millirem per year, was imposed for transportation workers or state inspectors, maximally exposed individual doses would be lower. See DIRS 156764-DOE (1999, Article 211) for DOE guidance on occupational dose limits.
d. Person in a traffic jam is assumed to be exposed one time only.
e. Assumes the person works at the service station for all 24 years of operations. Mitigation would be required to reduce impacts to members of the public to below 100 millirem per year.

Impacts to the maximally exposed individuals in the general public would be very low. The highest impacts would be to a service station employee who worked at a station where the analysis assumed all truck shipments would stop under the mostly legal-weight truck scenario (Table 6-9). The analysis estimated that this employee would receive a dose of 2.4 rem over 24 years, which corresponds to the maximum that would be allowed (100 millirem per year) for a member of the general public under regulations in 10 CFR Part 20. The estimate assumes that measures would be taken by DOE to reduce the dose to the employee from 130 millirem per year (3.2 rem over 24 years)—the dose estimated by the analysis if dose reduction measures were not implemented. The estimate of 3.2 rem over 24 years conservatively assumed the person would be exposed to 450 truck shipments each year for 24 years. For perspective, under the mostly legal-weight truck scenario, which assumes an average of 2,200 legal-weight truck shipments per year, about 450 truck shipments would pass through the Mercury, Nevada, gate to the Nevada Test Site in 1,800 hours. A worker at a truck stop along the route to Mercury would work about 1,800 hours per year. Thus, if every shipment stopped at that truck stop, the maximum number of shipments the worker would be exposed to in a year would be 450.

Impacts from Vehicle Emissions. Using data published by DIRS 151198-Biwer and Butler (1999, p. 1165 to 1166), DIRS 155786-EPA (1997, all), and DIRS 155780-EPA (1993, Section 13.2.13) (see Appendix J, Section J.1.3.2.3), DOE estimated the number of fatalities that vehicle emissions from shipments to Yucca Mountain could cause (Table 6-10). These potential impacts would result principally from exposure to increases in levels of pollutants, where the additional pollutants would come from vehicles transporting spent nuclear fuel and high-level radioactive waste and the accompanying escort vehicles. In the context of the number of vehicle kilometers from shipments to the Yucca Mountain site, these emissions would be very small in comparison to the emissions from other vehicles.

Table 6-10. Population health impacts from vehicle emissions during incident-free transportation for national mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel	Total[b]
Estimated vehicle emission-related fatalities	0.93	0.01	0.95

a. Impacts are totals for shipments over 24 years.
b. Total differs from sums of values due to rounding.

This section addresses radiological and nonradiological impacts to populations and maximally exposed individuals from the incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail national transportation scenario. In addition, it identifies impacts of legal-weight truck shipments that would occur under the mostly rail scenario for the six commercial sites that do not have the capability to load rail casks (about 1,079 legal-weight truck shipments over 24 years). Of these six sites, two have direct rail access and four have indirect access. Of the four sites with indirect access, three have barge access. The analysis assumed that the six legal-weight truck sites would upgrade their crane capacities and ship by rail after reactor shutdown.

6.2.3.2 Impacts from Incident-Free Transportation – National Mostly Rail Transportation Scenario

For this analysis, DOE assumed that it would use either a branch rail line or heavy-haul trucks in Nevada to transport rail casks to and from the repository. Accordingly, the results indicate the range of impacts for the rail and heavy-haul truck implementing alternatives that DOE could use for transportation to the repository after rail shipments arrived in Nevada. Section 6.3 and Appendix J present more information on the analysis of the environmental impacts of the Nevada rail and heavy-haul implementing alternatives. Appendix J, Section J.2, also presents a comparison of the effects of using dedicated trains or general freight services for rail shipments.

The mostly rail scenario assumes that the 24 commercial sites not served by a railroad but with the capability to handle rail casks would use heavy-haul trucks to transport the casks to railheads for transfer to railcars. In addition, 17 of the 24 sites are adjacent to navigable waterways. At some of the 17 sites on navigable waterways, barges could be used for the initial trip segments (see Appendix J, Section J.2.1). The impacts estimated by the analysis include the impacts of heavy-haul truck or barge shipments of rail casks from the 24 sites to nearby railheads.

The analysis assumed that the truck shipments of spent nuclear fuel and high-level radioactive waste would make periodic stops for state inspections, changes of drivers, rest, and fuel. Rail shipments would

VEHICLE EMISSION UNIT RISK FACTORS

DIRS 151198-Biwer and Butler (1999, all) presents unit risk factors for estimating vehicle emissions and the resulting health effects (fatalities) from truck and rail transportation. Changes to information used in the Biwer and Butler analysis resulted in revised factors used in the analyses in this EIS. DOE made four changes:

- *Fugitive dust emission factor*. Biwer and Butler used the paved road fugitive dust emission factor equation from DIRS 155786-EPA (1997, Volume 1, Supplement D, Section 13.2.1) to estimate fugitive dust emission factors for individual vehicle weight classes. The emission factor used in the Final EIS analysis is based on the fleet average weight, as recommended in the reference.

- *Diesel exhaust emission factor*. Biwer and Butler used diesel exhaust emission factors for trucks operating in 1995. The Final EIS analysis used information presented in the *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, all) to estimate diesel exhaust emission factors projected for the fleet of trucks operating in 2010.

- *Mortality rate used to estimate health effects*. The PM_{10} risk factor used in Biwer and Butler was calculated using a baseline mortality rate of 0.008. This is the crude rate, which is influenced by age differences in population composition. The analysis for the Final EIS used an age-adjusted mortality rate of 0.005.

- *PM_{10} risk factor*. The PM_{10} health risk factor used by Biwer and Butler was based on an upper bound reported by DIRS 152600-Ostro and Chestnut (1998, all), who also presented lower-bound and central estimates. To avoid compounding conservative assumptions, the Final EIS analysis uses the central estimate.

These changes resulted in values for vehicle emission health effect (fatality) unit risk factors that are about a factor of 30 smaller that those estimated by DIRS 151198-Biwer and Butler (1999, all).

also make periodic stops. However, the assumed frequency of the stops and the numbers of people nearby would be different from those for truck shipments and would result in a lower dose.

Incident-Free Radiological Impacts to Populations. Table 6-11 lists incident-free radiological impacts that would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste under the mostly rail national transportation scenario. Because national impacts would result from transportation from the commercial and DOE sites to the repository, they include impacts from a Nevada rail or heavy-haul truck implementing alternative. For the case in which rail shipments would continue in Nevada, total impacts to members of the general public would differ depending on the implementing alternative (see Section 6.3.2 for additional details). The range of values listed in Table 6-11 includes the range of impacts from the Nevada implementing alternatives.

About 1 latent cancer fatality could result from shipments of spent nuclear fuel and high-level radioactive waste under the mostly rail scenario over 24 years. The latent cancer fatality would occur over the lifetime of an individual in the exposed population. The population within 800 meters (0.5 mile) of routes in which this fatality would occur would be approximately 16.4 million. Approximately 3.8 million members of this population would incur fatal cancers from all other causes not associated with the Proposed Action (DIRS 153066-Murphy 2000, p. 5).

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-12 lists the results of risk calculations for maximally exposed individuals for the mostly rail transportation scenario over 24 years. Truck and rail crew members would receive the highest doses. The mostly rail scenario would require transport crews for legal-weight trucks (1,079 total shipments over 24 years) and for rail

Table 6-11. Population doses and radiological impacts from incident-free transportation for national mostly rail scenario.[a]

Category	Legal-weight truck shipments	Rail shipments[b,c]	Totals[d]
Involved workers			
Collective dose (person-rem)	360	3,300 - 4,300	3,700 - 4,600
Estimated LCFs[e]	0.14	1.3 - 1.7	1.5 - 1.9
Public			
Collective dose (person-rem)	130	1,100 - 1,500	1,200 - 1,600
Estimated LCFs	0.07	0.55 - 0.76	0.61 - 0.81

a. Impacts are totals for 24 years.
b. Barge transportation to a railhead on navigable waterways could be used for transportation from 17 commercial sites that do not have rail service but can load a rail cask. See Appendix J.
c. Includes impacts from intermodal transfer station operations.
d. Totals might differ from sums of values due to rounding.
e. LCF = latent cancer fatality.

Table 6-12. Estimated doses and radiological impacts to maximally exposed individuals for national mostly rail scenario.[a,b]

Receptor	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (rail, heavy-haul truck, or legal-weight truck)	48[c]	0.02
Escort	48[c]	0.02
Inspector (rail)	34	0.014
Railyard crew member	4.2	0.0017
Public		
Resident along route (rail)	0.0016	0.0000008
Person in traffic jam (legal-weight truck)	0.016	0.000008
Person at service station (legal-weight truck)	0.075	0.000038
Resident near rail stop	0.29	0.00014

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years.
c. Based on 2-rem-per-year administrative dose limit. If a lower dose limit, for example 500 millirem per year, was imposed for transportation workers or state inspectors, maximally exposed individual doses would be lower. See DIRS 156764-DOE (1999, Article 211) for DOE guidance on occupational dose limits.

shipments. Individual crew members who operated legal-weight trucks and escorts for rail shipments could be exposed to as much as 48 rem over 24 years of operations (maximum exposure of 2 rem each year). State inspectors who would conduct frequent inspections of rail shipments could receive annual radiation doses as high as 1.4 rem (see Appendix J, Section J.1.3.2.2.2). Escorts traveling with rail shipments could be exposed to up to 48 rem over 24 years of operations (maximum exposure of 2 rem per year; see Appendix J, Section J.1.3.2.2.3).

Impacts from Vehicle Emissions. Less than 1 (a range from 0.55 to 0.77) fatality could result from exposure to vehicle emissions over 24 years under the mostly rail scenario. This potential would arise principally from exposure of people in urban areas to very small increases in levels of pollutants caused by vehicles transporting spent nuclear fuel and high-level radioactive waste.

6.2.4 ACCIDENT SCENARIOS

6.2.4.1 Loading Accident Scenarios

The analysis used existing information from several different sources (DIRS 104794-CRWMS M&O 1994, all; DIRS 103177-CP&L 1989, all; DIRS 103449-PGE 1996, all; DIRS 101816-DOE 1997, all) to estimate potential radiological impacts from accidents involving the loading of spent nuclear fuel or high-level radioactive waste for shipment and handling of shipping casks. As summarized below, the results in these sources indicate that, because no cask would be likely to be breached and thus no radionuclides released, there would be no or very small potential radiological consequences for the public and for workers from accidents in all cases. Appendix J, Section J.1.3.1, presents a description of typical operations for loading spent nuclear fuel in a shipping cask at a commercial facility.

Lift-handling incidents involving spent nuclear fuel in a transfer facility would have an estimated probability of 0.0001 (1 in 10,000) per handling operation (DIRS 104794-CRWMS M&O 1994, pp. 3 to 8). The estimated collective dose to workers from the incidents would be no more than 0.1 person-rem, and it would be much less to the public.

The total number of high-level radioactive waste canisters potentially handled would be approximately the same as the number of spent nuclear fuel canisters, and handling operations would be similar. DOE expects the consequences of handling incidents that involved high-level radioactive waste would be less than those involving spent nuclear fuel (DIRS 103237-CRWMS M&O 1998, p. 3). Thus, impacts from high-level waste handling would be less than the estimated 0.1 person-rem from a spent nuclear fuel handling accident.

Reports on independent spent fuel storage installations and previous DOE analyses provide further evidence of the low probable impacts associated with a loading accident. Safety analysis reports prepared for independent spent fuel storage installations at the Trojan Nuclear Station and the Brunswick Steam Electric Plant concluded that there would be no or low radiological consequences from accidents that could occur at such facilities (DIRS 103449-PGE 1996, Section 8.2; DIRS 103177-CP&L 1989, Section 8.2). This analysis examined the potential magnitude of impacts from spent nuclear fuel storage facility operations. Similarly, previous DOE analyses (DIRS 101816-DOE 1997, all; DIRS 104794-CRWMS M&O 1994, all) indicate that radiological consequences from accidents involving spent nuclear fuel and high-level radioactive waste management activities would be very small (Table 6-12). The low consequences listed in Table 6-13 are consistent with the results from an earlier DOE analysis (DIRS 104731-DOE 1986, Volume 2, p. xvii).

Table 6-13. Radiological consequences of accidents associated with handling and loading operations.

Affected group	Impact (per year)[a]	24-year impact	Source
Involved workers			
Maximally exposed involved worker			
Dose (rem)	0.0005	0.01	--[b]
Probability of LCF[c]	0.0000002	0.000005	--
Worker population			
Collective dose (person-rem)	0.1	2.4	DIRS 104794-CRWMS M&O (1994, p. 3-8)
Number of LCFs	0.00004	0.001	--
Noninvolved workers			
Maximally exposed noninvolved worker			
Dose (rem)	0.0002	0.005	--
Probability of LCF	0.00000005	0.000001	--
Public			
Maximally exposed individual			
Dose (rem)	0.0013	0.03	--
Probability of LCF	0.0000007	0.00002	--
Population			
Collective dose (person-rem)	0.000074	0.002	DIRS 104794-CRWMS M&O (1994, p. 3-8)
Number of LCFs	0.00000004	0.000001	--

a. Average annual impact for 24 years.
b. -- = determined by analysis.
c. LCF = latent cancer fatality.

6.2.4.2 Transportation Accident Scenarios

Accidents could occur during the transportation of spent nuclear fuel and high-level radioactive waste. This section describes the risks and impacts to the public and workers for a range of accident scenarios including those that are highly unlikely but that could have high consequences (called *maximum reasonably foreseeable accident scenarios*) and those that are more likely but that would have less severe consequences. The impacts would include those to the population and to hypothetical maximally exposed individuals. The following paragraphs describe the analysis approach. Appendix J, Section J.1.4, contains more details.

The analysis did not address accident impacts to workers apart from impacts to the public. For example, fatalities from train and truck accident scenarios would include fatalities for vehicle operators. The collective radiological risk from accidents to highway vehicle and train crews would be much less than for the public because of the large difference in the numbers of individuals that could be affected. In addition, based on national accident statistics, motor carrier and train operators are much less likely to be fatalities in nonradiological accidents than operators of other vehicles (DIRS 103410-DOT 1998, p. 30).

MAXIMUM REASONABLY FORESEEABLE ACCIDENT SCENARIOS

Maximum reasonably foreseeable impacts from accident scenarios for the transportation of spent nuclear fuel and high-level radioactive waste would be characterized by extremes of mechanical (impact) forces, heat (fire), and other conditions that would lead to the highest reasonably foreseeable consequences. For postulated accident scenarios such as these, the forces and heat would exceed the regulatory design limits of transportation cask structures and materials. (The performance of transportation casks was demonstrated through a combination of tests and analyses.) In addition, these forces and heat would be applied to the structures and surfaces of a cask in a way that would cause the greatest damage and bring about releases of radioactive materials to the environment. The most severe accident scenarios analyzed in this chapter would release radioactive material. These accident scenarios correspond to those in the highest accident severity category, which represent events that would be very unlikely but, if they occurred, would result in human health effect consequences.

In general, this EIS considers accidents with conditions that have a chance of occurring more often than 1 in 10 million times in a year to be reasonably foreseeable. Accidents and conditions less likely than this are not considered to be reasonably foreseeable.

The specific number, location, and severity of an accident can be predicted only in general terms of the likelihood of occurrence (the probability). Similarly, the weather conditions at the time an accident occurs cannot be precisely predicted. Therefore, the EIS analysis evaluated a variety of accident scenarios and conditions to understand the influence of various conditions on environmental impacts. The analysis of impacts to populations along routes assumed that an accident could occur at any location along a route.

The EIS analysis considered accident scenarios based on the 19 truck and 21 rail accident cases presented by DIRS 152476-Sprung et al. (2000, all). Appendix J, Section J.1.4.2.1, describes those cases and their derivations. In addition, the analysis estimated impacts of postulated releases from accident scenarios in three population zones—urban, suburban, and rural—under a set of meteorological (weather) conditions that represent the national average meteorology. The analysis used state-specific accident data, the lengths of routes in the population zones in states through which the shipments would pass, and the number of shipments that would use the routes to determine accident scenario probabilities.

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The EIS analysis used the properties of a representative commercial spent nuclear fuel along with the properties for the 15 categories of DOE spent nuclear fuel and high-level radioactive waste described in Appendix A. Since the publication of the Draft EIS, DOE has reevaluated the properties of commercial spent nuclear fuel that it used in analyses of transportation accidents and determined that the representative spent nuclear fuel described in Appendix A is more appropriate for analysis of such accidents. Representative commercial spent nuclear fuel would be (1) fuel discharged after 14 years from a boiling-water reactor with a burnup of 40,000 megawatt-days per MTHM and (2) fuel discharged from a pressurized-water reactor after 15 years with a burnup of 50,000 megawatt-days per MTHM. Because representative spent nuclear fuel would be younger and have higher burnup than typical spent nuclear fuel, its relative health and safety hazard would be greater. In fact, the hazard is about 2 times greater. As a consequence, estimates of impacts of transportation accidents involving casks containing representative spent nuclear fuel would be about 2 times greater than if the casks contained typical spent nuclear fuel.

TRANSPORTATION EMERGENCIES

Under Section 180(c) of the Nuclear Waste Policy Act, as amended, the Department would provide technical assistance and funding for training of local and American Indian public safety officials of eligible states and tribes in relation to transportation under the Proposed Action. The training would cover safe routine transportation and emergency response procedures. DOE would also require its transportation contractors to comply with *Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents Involving Truckload Quantities of Radioactive Materials* (DIRS 156289-ANSI 1987, Section 5.2). This standard requires the preparation of an emergency response plan and describes appropriate provisions of information and assistance to emergency responders. The standard also requires the carrier to provide appropriate resources for dealing with the consequences of the accident including isolating and cleaning up spills, and to maintain working contact with the responsible governmental authority until the latter has declared the incident to be satisfactorily resolved and closed. DOE would, as requested, assist state, tribal, and local governments in several ways to reduce the consequences of accidents related to the transportation of spent nuclear fuel and high-level radioactive waste. In addition, DOE maintains an emergency response program through eight Regional Coordinating Offices across the United States. These offices are capable of responding to transportation radiological emergencies and are on call 24 hours a day. They respond to requests for radiological assistance from state or tribal authorities. Other DOE, Federal Emergency Management Agency, and U.S. Department of Transportation programs have provided training for transportation emergencies for many areas (for example, Colorado and South Carolina to support preparation for transportation for the Foreign Research Reactor and Waste Isolation Pilot Plant programs). Appendix M contains additional detail.

In addition to the risk due to accidents involving a release of radioactive material, the analysis examined the impacts of loss-of-shielding accidents. The loss-of-shielding scenarios range from an accident with no loss of shielding to a low-probability severe accident involving both a loss of shielding (and any increased direct exposure) and a release of some of the contents of the cask.

The EIS analysis also estimated impacts from an unlikely but severe accident scenario called a *maximum reasonably foreseeable accident* to provide perspective about the consequences for a population that might live nearby. For maximum reasonably foreseeable accident scenarios, the consequences were estimated for each of the accident scenarios and for both truck and rail casks from the spectrum of accidents presented in DIRS 152476-Sprung et al. (2000, all). For each accident scenario, possible combinations of weather conditions, population zones, and transportation modes were considered. The scenarios were then ranked according to those that would have a likelihood greater than 1 in 10 million per year and would have the greatest consequences (see Appendix J).

REEXAMINATION OF SPENT FUEL SHIPMENT RISK ESTIMATES

Factors other than the environment can cause uncertainties in the prediction of accident impacts. Uncertainty can result from both limited data and the limitations of computer models used to predict accident impacts. The first comprehensive study that developed estimates of the impacts of severe accidents was the *Shipping Container Response to Severe Highway and Railway Accident Conditions* (DIRS 101828-Fischer et al. 1987, all; also called the *Modal Study*) for fractions of shipping cask contents (spent nuclear fuel or high-level radioactive waste) that such accident scenarios could release to the environment. The estimates of severe accident impacts developed in the Modal Study were reexamined by Sandia National Laboratories in *Re-Examination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, all) published in April 2000. The Nuclear Regulatory Commission staff, in a memorandum to the Commissioners, concluded "the best estimate spent-fuel shipment risks from the reexamination appear to be less than the 'Modal Study'-based estimates by as much as 2 orders of magnitude" (DIRS 155562-NRC 2000, all). Although the Commission staff offered this positive finding, it also observed that several questions on the Sandia methodology require resolution before the best-estimate results can be completed. Even though it expressed caution regarding its findings, on the basis of the results presented the Commission staff concluded "the transportation risk studies provide a technical basis for determining that current regulations are sufficient to prevent releases of radioactive material during transport" (DIRS 155562-NRC 2000, all).

6.2.4.2.1 *Impacts from Accidents – National Mostly Legal-Weight Truck Scenario*

This section summarizes the potential impacts and risks associated with accidents under the legal-weight truck scenario. The impacts and risks include those associated with the legal-weight truck and rail shipments to Nevada plus the transfer of the spent nuclear fuel and high-level waste to heavy-haul trucks and its transportation in Nevada. The section summarizes radiological impacts for six accident scenario categories, under two types of weather conditions, and in three population densities (urban, suburban, and rural), in terms of a collective dose risk and consequence (latent cancer fatalities). It describes the potential impacts from the maximum reasonably foreseeable accident scenario separately. It also describes nonradiological impacts in terms of accident fatalities.

Radiological Impacts to Populations from Accidents. Based on state-specific accident rates, the total estimated number of traffic accidents under the Proposed Action for the mostly legal-weight truck scenario would be 66, or 2.8 per year. The collective radiological accident dose risk, as described in Appendix J, Section J.1.4.2.1, would be less than 1 (0.5) person-rem for the population within 80 kilometers (50 miles) along routes for the national mostly legal-weight truck scenario. This calculated risk would be the total for 24 years of shipment operations. The radiological dose risk of accidents is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. A radiological dose risk of 0.5 person-rem would be likely to cause much less than 1 (0.0002) latent cancer fatality, or approximately 2 chances in 10,000 of 1 latent cancer fatality among the more than 10 million persons within 80 kilometers of the routes that the shipments would use. The 0.5 person-rem risk includes the dose risk associated with loss-of-shielding events. The accident risk for legal-weight truck shipments dominates the total risk, contributing more than 99.9 percent of the population dose and risk in comparison to the risk associated with the 300 proposed shipments of naval spent nuclear fuel.

Consequences of Maximum Reasonably Foreseeable Accident Scenario. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario in urbanized and rural population zones for both legal-weight truck and rail shipments under the mostly legal-weight truck scenario. The maximum reasonably foreseeable transportation accident scenario that would have the greatest consequences for the mostly legal-weight truck scenario (a probability of approximately 3 in 10 million per year) would be a long-duration severe fire accident in which the transportation cask was fully engulfed by the fire. This accident is further described by DIRS 152476-Sprung et al. (2000, p. 7-25) as case 18 in accidents evaluated for legal-weight truck casks (see Appendix J, Section J.1.4.2.1). The analysis assumed that the accident would occur under stable (slowly dispersing atmospheric conditions that would not be exceeded 95 percent of the time) meteorological conditions in an urban area. Severe accidents in other population zones under stable or neutral weather conditions (atmospheric conditions that would not be exceeded 50 percent of the time) would have smaller consequences. The accident scenario assumes a breach of the shipping cask and the release of a portion of its contents to the air. This accident in combination with stable atmospheric conditions would be very unlikely (2.3 in 10 million per year). Table 6-14 summarizes the impacts of the accident scenario. This accident scenario could cause 0.55 latent cancer fatality; in comparison, a population of 5 million within 80 kilometers (50 miles) of the center of a large U.S. metropolitan area such as that assumed in the analysis would be likely to experience more than 1.1 million lifetime cancer fatalities from other causes not related to the Proposed Action (DIRS 153066-Murphy 2000, p. 5). For this accident scenario, the analysis projected that most of the dose to a population would come from inhalation, cloudshine, and groundshine sources. The maximally exposed individual, assumed to be about 150 meters (490 feet) from the accident where particles heated by the accident would fall after cooling, would receive a dose of about 0.8 rem (Table 6-14). A first responder to this accident would receive a small dose (2.6 millirem).

Table 6-14. Estimated radiological impacts of maximum reasonably foreseeable accident scenario for national mostly legal-weight truck scenario.

Impact	Urbanized area (stable atmospheric conditions)
Accident scenario probability (annual)	0.00000023 per year (about 2.3 in 10 million)
Impacts to populations	
Population dose (person-rem)	1,100
Latent cancer fatalities	0.55
Impacts to maximally exposed individuals	
Maximally exposed individual dose (rem)	3
Probability of a latent cancer fatality	0.0015
Impacts to first responder	
Maximally exposed responder dose (rem)	0.26
Probability of latent cancer fatality	0.0000013

In addition to a maximum reasonably foreseeable accident, DOE evaluated other severe accidents. Appendix J, Section J.1.4.2.1, describes these accidents and their potential impacts. The accident conditions for one truck accident (Case 11) could be similar to those from a crash of a commercial jet airliner into a legal-weight truck cask (DIRS 157210-BSC 2001, all). The consequences of this accident (1,100 person-rem or 0.55 latent cancer fatality) would be about the same as those for the maximum reasonably foreseeable truck accident described above.

Section J.1.4.2.5 in Appendix J summarizes studies of potential economic and environmental impacts of hypothetical severe transportation accidents that would release radioactive materials from transportation casks.

Impacts from Traffic Accidents. Approximately 5 (4.9) traffic fatalities could occur in the course of transporting spent nuclear fuel and high-level radioactive waste under the mostly legal-weight truck national transportation scenario during the 24 years of operations for the Proposed Action. Essentially all of these fatalities would be from truck operations; none would occur from the 300 railcar shipments of naval spent nuclear fuel. The fatalities would be principally from traffic accidents; half would involve trucks transporting loaded casks to the repository and half would involve returning shipments of empty casks. The fatalities would occur over 24 years and approximately 380 million kilometers (240 million miles) of highway travel. Based on information extrapolated from the U.S. Department of Transportation

Bureau of Transportation Statistics (DIRS 150989-BTS 1998, p. 20), during the same 24-year period about 1 million deaths would be likely to occur in traffic accidents on U.S. highways.

6.2.4.2.2 *Impacts from Accidents – National Mostly Rail Transportation Scenario*

This section discusses the results of the analysis of radiological impacts to populations and maximally exposed individuals and of traffic fatalities that would arise from accidents during the transportation of spent nuclear fuel and high-level radioactive waste for the national mostly rail transportation scenario.

DOE used the models and calculations described in Appendix J, Section J.1.4.2.1, to estimate the impacts from rail accidents, and included impacts postulated to occur during the transportation of commercial spent nuclear fuel by legal-weight trucks from six commercial sites that do not have the capability to handle or load large rail casks. The analysis also included the impacts from accidents for heavy-haul truck or barge shipments to nearby railheads from 24 commercial sites that have the capability to load a rail cask but are not served by a railroad. DOE used the models and calculations described in Appendix J to estimate the impacts. Appendix J, Section J.2.4, presents additional information on heavy-haul truck and barge transportation from the 24 commercial sites.

Accident Radiological Impacts for Populations. Based on state-specific accident rates, the total estimated number of rail and truck traffic accidents under the Proposed Action for the mostly rail scenario would be about 10, or about 0.4 per year. The collective radiological dose risk of accidents would be approximately 1 (0.89) person-rem for the population within 80 kilometers (50 miles) along routes for the national mostly rail transportation scenario. This calculated dose risk would be the total for 24 years of shipment operations. The radiological dose risk of accidents is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. A radiological dose risk of 1 person-rem would be likely to cause much less than 1 (0.00045) latent cancer fatality.

Radiological risks from accidents for the mostly rail scenario would include impacts associated with about 9,646 railcar shipments (one cask to a railcar) and 1,079 legal-weight truck shipments. National rail transportation of spent nuclear fuel and high-level radioactive waste would account for most of the population dose and risk to the public.

Impacts of Maximum Reasonably Foreseeable Accident Scenario. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario in urbanized areas or rural population zones and under stable and neutral atmospheric conditions. The maximum reasonably foreseeable accident scenario under the mostly rail scenario would involve a release of a fraction of the contents of a rail cask in an urban area under stable meteorological conditions (slowly dispersing atmospheric conditions that would not be exceeded 95 percent of the time), where *atmospheric dispersion* of contaminants would occur more slowly only 5 percent of the time. This accident scenario would have a likelihood of about 2.8 in 10 million per year, and would result in about 5 latent cancer fatalities in the population (Table 6-15). The maximally exposed individual, assumed to be about 330 meters (1,080 feet) from the accident, would receive a dose of about 29 rem. An accident that involved high impact forces or a long-duration fire could reduce the effectiveness of the radiation shielding in a shipping cask. A first responder to this accident could receive a dose of as much as 0.83 rem.

Actual transportation accidents involve collisions of many kinds, such as with other vehicles and roadside objects, involvement in fires and explosions, inundation, and burial. These accidents are caused by a variety of initiating events including human error, mechanical failure, and natural causes such as earthquakes. Accidents occur in many different kinds of places including mountain passes and urban areas, rural freeways in open landscapes, and rail switching yards. Thus, there are as many different kinds of unique initiating events and accident conditions as there are accidents. DOE could not

Table 6-15. Estimated impacts from maximum reasonably foreseeable accident scenario for national mostly rail transportation scenario.

Impact	Urbanized area (stable atmospheric conditions)
Accident probability	0.00000028 per year (about 2.8 in 10 million)
Impacts to populations	
Population dose (person-rem)	9,900
Latent cancer fatalities	5
Impacts to maximally exposed individuals	
Maximally exposed individual dose (rem)	29
Probability of a latent cancer fatality	0.01
Impacts to first responder	
Maximally exposed responder dose (rem)	0.83
Probability of latent cancer fatality	0.0004

practicably attempt to analyze every possible accident that could occur. Instead, DOE analyzed a broad range of accidents, each of which represents a grouping of initiating events and conditions having similar characteristics. For example, the EIS analyzes the impacts of a collection of collision accidents in which a cask would be exposed to impact velocities in the range of 60 to 90 miles per hour (see Appendix J, Section J.1.4.2.1).

In addition, the EIS analyzes a maximum reasonably foreseeable accident in which a collision would not occur but the temperature of a rail cask containing spent nuclear fuel would rise to between 750ºC and 1,000ºC (between 1,400ºF and 1,800ºF) (Section 6.2.4.2). The conditions of the maximum reasonably foreseeable accident analyzed in the EIS envelop conditions reported in newspapers for the Baltimore Tunnel fire (a train derailment and fire that occurred in July 2001 in a tunnel in Baltimore, Maryland). Temperatures in that fire were reported to be as high as 820ºC (1,500ºF) and the fire was reported to have burned for up to 5 days (DIRS 156753-Ettlin 2001, all; DIRS 156754-Rascovar 2001, all).

DOE evaluated other severe accidents. Appendix J, Section J.1.4.2.1, describes these accidents and their potential impacts. The accident conditions for one rail accident (Case 4) could be similar to those from a crash of a commercial jet airliner into a rail cask (DIRS 157210-BSC 2001, all). The consequences of this accident (1,300 person-rem or 0.65 latent cancer fatality) would be less than those for the maximum reasonably foreseeable rail accident described above.

Impacts From Traffic Accidents. The analysis estimated that across the United States approximately 3 (3.1) traffic and train accident fatalities could occur during transportation of spent nuclear fuel and high-level radioactive waste under the national mostly rail transportation scenario. Half of the fatalities would occur during the return of empty casks to commercial and DOE sites. Essentially all of the fatalities would involve train operations; about half would involve highway vehicles hit by trains. There would be about a 12-percent chance of 1 fatality from the 1,079 legal-weight truck shipments of commercial spent nuclear fuel. This fatality could happen during the 24 years of transportation operations involving approximately 77 million kilometers (48 million miles) of railcar travel and 10 million kilometers (6 million miles) of highway travel. On the basis of data presented by the Bureau of Transportation Statistics (DIRS 150989-BTS 1998, p. 20), during the same 24-year period about 1 million people will die in traffic accidents on U.S. highways.

6.2.4.2.3 *Impacts of Acts of Sabotage*

The Nuclear Regulatory Commission has developed a set of rules specifically aimed at protecting the public from harm that could result from sabotage of spent nuclear fuel casks. Known as physical protection and safeguards regulations (10 CFR 73.37), these security rules are distinguished from other regulations that deal with issues of safety affecting the environment and public health. The objectives of the physical protection and safeguard regulations are to:

- Minimize the possibility of sabotage
- Facilitate recovery of spent nuclear fuel shipments that could come under control of unauthorized persons

To achieve these objectives, the Nuclear Regulatory Commission physical protection and safeguard rules require:

- Advance notification of each shipment to the Nuclear Regulatory Commission, the states, and Native American governments [proposed rulemaking 10 CFR Parts 71 and 73 (64 *FR* 71331, December 21, 1999)]
- The licensee to have current procedures to cope with safeguards emergencies
- Instructions for escorts on how to determine if a threat exists and how to deal with it
- Maintenance of a communications center to monitor continually the progress of each shipment
- A written log describing the shipment and significant events during the shipment
- Advance arrangements with law enforcement agencies along the route
- Advance route approval by the Nuclear Regulatory Commission
- Avoidance of intermediate stops to the extent practicable
- At least one escort to maintain visual surveillance of the shipment during stops
- Shipment escorts to report status periodically
- Armed escorts in heavily populated areas
- Onboard communications equipment
- Protection of specific shipment information

The cask safety features that provide containment, shielding and thermal protection also provide protection against sabotage. The casks would be massive. The spent nuclear fuel in a cask would typically be only about 10 percent of the gross weight; the remaining 90 percent would be shielding and structure.

It is not possible to predict whether sabotage events would occur and, if they did, the nature of such events. Nevertheless, DOE examined various accidents, including an aircraft crash into a transportation cask. The consequences of both the maximum reasonably foreseeable accident and the aircraft crash are presented above for the mostly truck and mostly rail transportation scenarios and can provide an approximation of the types of consequences that could occur from a sabotage event. DOE also considered the consequences of a potential successful sabotage attempt on a cask. A study conducted by Sandia National Laboratories (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) estimated the amounts and characteristics of releases of radioactive materials from rail and truck casks subjected to the effects of two different devices.

Devices considered in the Sandia study (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) included possible devices that might be used in acts of sabotage against shipping casks. (Note: The shield walls of shipping casks for spent nuclear fuel and high-level radioactive waste are similar to the massive layered construction used in armored vehicles such as tanks.) These kinds of devices were demonstrated by the study to be capable of penetrating a cask's shield wall, leading to the dispersal of contaminants to the environment.

The truck cask design selected for analysis was the General Atomics GA-4 Legal-Weight Truck Cask. This cask, which uses uranium for shielding, is a state-of-the-art design recently certified by the Nuclear Regulatory Commission to ship four pressurized-water reactor nuclear fuel assemblies (DIRS 148184-NRC 1998, all). The rail cask design used was based on the conceptual design developed by DOE for the dual-purpose canister system. This design is representative of large rail casks that could be certified for shipping spent nuclear fuel and high-level radioactive waste.

DOE used the RISKIND code (DIRS 101483-Yuan et al. 1995, all) to evaluate the radiological health and safety impacts of the estimated releases of radioactive materials. The analysis used assumptions about the concentrations of radioisotopes in spent nuclear fuel, population densities, and atmospheric conditions (weather) used to evaluate the maximum reasonably foreseeable accidents.

Because it is not possible to forecast the location or the environmental conditions that might exist for acts of sabotage, the analysis determined consequences for urbanized areas (see Appendix J, Section J.1.4.2.1) under neutral (average) weather conditions.

For legal-weight truck shipments, the analysis estimated that a sabotage event occurring in an urbanized area could result in a population dose of 96,000 person-rem. This dose would cause an estimated 48 fatal cancers among the population of exposed individuals. A maximally exposed individual could receive a lifetime committed dose of 110 rem, which would increase the risk of a fatal cancer from about 23 percent from all other causes to about 29 percent.

These estimates exceed those presented in the Draft EIS for two reasons. The analysis for this section assumed that the cask would contain representative (or average hazard) spent nuclear fuel. The analysis in the Draft EIS assumed that the cask would contain typical (or average age) spent nuclear fuel. The amount of radioactivity in representative spent nuclear fuel is about twice that in typical spent nuclear fuel. In addition, the analysis in the Draft EIS used urban area populations reported in the 1990 Census, whereas the analysis for this section used populations projected to 2035. The population estimates used for 2035 are about 40 percent greater than those reported by the 1990 Census. The combined result of these changes is that the estimated consequences of an act of sabotage against a transportation cask in this section are about 3 times those estimated in the Draft EIS.

The consequences estimated for an act of sabotage involving a rail shipment would be less than those estimated for a legal-weight truck shipment. The smaller consequence for the rail shipment would be because less of the radionuclides would be released from a rail transportation cask than from a legal-weight truck transportation cask (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all). For rail shipments, the analysis estimated that a sabotage event in an urbanized area could result in a population dose of 17,000 person-rem. This dose would be likely to cause an estimated 9 fatal cancers among the population of exposed individuals. A maximally exposed individual could receive a lifetime committed dose of 40 rem, which would increase the risk of a fatal cancer from about 23 percent from all other causes to about 25 percent.

Because of the attacks on September 11, 2001, the Department and other agencies are reexamining the protections built into our physical security and safeguards systems for transportation shipments. As dictated by results of this reexamination, DOE would modify its methods and systems as appropriate.

6.2.5 ENVIRONMENTAL JUSTICE

Shipments of spent nuclear fuel and high-level radioactive waste would use the Nation's existing railroads and highways. DOE expects that transportation-related impacts to land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small. In addition, as described in the preceding sections, incident-free transportation and the risks from transportation accidents (the maximum reasonably foreseeable accident scenario would have about 3 chances in 10 million of occurring per year) would not present a large health or safety risk to the population as a whole, or to workers or individuals along national transportation routes. The low effect on the population as a whole also would be likely for any segment of the population, including minorities, low-income groups, and members of Native American tribes.

A previous DOE analysis of the potential for environmental justice concerns from the transportation of DOE spent nuclear fuel to the Idaho National Engineering and Environmental Laboratory (DIRS 101802-DOE 1995, Volume 1, pp. L-2 and L-36) also concluded that impacts to minority and low-income populations and to populations of American Indians in Idaho would not be disproportionately high and adverse. As part of that analysis, DOE consulted with the Shoshone Bannock Tribe to analyze impacts to tribe members because the shipments in question would cross the Fort Hall Reservation. The analysis (DIRS 101802-DOE 1995, Volume 3, Part A, p. 3-32) concluded that risks to the health and safety of the potentially affected tribal population in Idaho from incident-free transportation and from accidents would be very low.

The EIS analyzes potential public health effects of both routine (incident-free) transportation of radioactive materials and transportation accidents involving radioactive materials. First, regarding routine transportation, the EIS considers air emissions and doses from exposure to radioactive materials during transport. The EIS estimates the impact from air emissions to be 1 emissions-related fatality. The EIS also estimates that the 24-year national transportation campaign would cause fewer than about 3 latent cancer fatalities among the public under the mostly legal-weight truck scenario and fewer under the preferred mostly rail scenario. Although many people would be exposed nationwide over a long campaign, the radiation dose to any exposed individual would be very low. In this context, DOE does not consider such impacts to be high. Because DOE does not know of a plausible mechanism under these circumstances whereby low-income or minority populations could incur high and adverse impacts when the general public would not, the Department believes there could be no disproportionately high and adverse impacts on low-income or minority populations.

The EIS estimates the number of people in the general public who could be killed by accidents involving transportation of spent fuel and high-level radioactive waste. The two mechanisms for such impacts are bodily trauma from collisions or exposure to radioactivity that would be released if a sufficiently severe accident occurred. The analysis estimated that the 24-year national campaign would cause fewer than 5 fatalities among the general public from trauma sustained in collisions with vehicles carrying spent nuclear fuel or high-level radioactive waste. In this context, DOE does not consider such impacts to be high. Again, DOE does not know of a plausible mechanism under these circumstances whereby low-income or minority populations could incur high and adverse impacts when the general public would not.

Only a severe accident that resulted in a considerable release of radioactive material could cause high and adverse health effects to the affected population. Because the risk of these high and adverse consequences applies to the entire population along all transportation routes, it would not apply disproportionately to any minority or low-income population.

Based on the analysis of incident-free transportation and transportation accidents in this EIS and the results of a transportation analysis conducted by DOE in a previous programmatic EIS, and the fact that

DOE has identified no subsection of the population that would be disproportionately affected by transportation related to the Proposed Action, DOE has concluded that no disproportionately high and adverse impacts would be likely on minority or low-income populations from the national transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

Section 6.3.4 discusses environmental justice in relation to transportation in Nevada. Chapter 4, Section 4.1.13.4, contains a discussion of a Native American perspective on the Proposed Action.

6.3 Nevada Transportation

The analysis of impacts from national transportation includes those from transportation activities in the State of Nevada. This section discusses Nevada transportation impacts separately to ensure that the impacts of alternative transportation modes in Nevada are apparent. Spent nuclear fuel and high-level radioactive waste shipped to the repository by legal-weight truck would continue in the same vehicles to the Yucca Mountain site. Material that traveled by rail would either continue to the repository on a newly constructed branch rail line or transfer to heavy-haul trucks at an intermodal transfer station that DOE would build in Nevada for shipment on existing highways that could require upgrades. Selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul truck routes, would require additional field surveys, environmental and engineering analysis, state, local, and Native American Tribal government consultation, and National Environmental Policy Act reviews.

The transportation analysis in the EIS treats the candidate legal-weight truck routes, rail corridors, and heavy-haul truck routes as current analysis tools and refers to them in the present tense. The EIS refers to impacts associated with these alternatives in the conditional voice *(would)* because they would not occur unless DOE proceeded with the Proposed Action. This convention is applied whenever the EIS discusses the transportation implementing alternatives.

This section describes potential impacts of three transportation scenarios and their respective implementing alternatives. The three transportation scenarios are (1) mostly legal-weight truck (corresponding to that portion of the national impacts that would occur in Nevada), (2) mostly rail, and (3) mostly heavy-haul truck.

The mostly legal-weight truck scenario does not include implementing alternatives. Under this scenario, highway shipments would be restricted to specific routes that satisfy the regulations of the U.S. Department of Transportation (49 CFR Part 397). Because the State of Nevada has not designated alternative preferred routes, only one combination of routes for legal-weight truck shipments would satisfy U.S. Department of Transportation routing regulations (I-15 to U.S. Highway 95 to Yucca Mountain). This scenario assumes that over 24 years approximately 300 shipments of naval spent nuclear fuel would arrive in Nevada by rail from the Idaho National Engineering and Environmental Laboratory and that heavy-haul trucks would transport them to the repository from a railhead.

The mostly rail scenario has five implementing alternatives, each of which includes a corridor with variations for a branch rail line in Nevada. Each implementing alternative includes the construction and operation of a rail line. These alternatives would include about 1,079 legal-weight truck shipments (about 45 per year) from 6 commercial sites that, while operational, would not have the capability to load rail casks.

The mostly heavy-haul truck scenario has implementing alternatives for five different routes on existing Nevada highways. The highways would have to be upgraded to enable heavy-haul trucks routinely to transport rail casks containing spent nuclear fuel and high-level radioactive waste from an intermodal transfer station to the repository. Each heavy-haul truck implementing alternative includes the construction and operation of an intermodal transfer station that DOE would use to transfer loaded rail casks from railcars to heavy-haul trucks and empty rail casks from the trucks to railcars. The analysis considered three potential intermodal transfer station locations. Each heavy-haul implementing alternative would also include 1,079 legal-weight truck shipments over 24 years from the 6 commercial sites that, while operational, would not have the capability to load rail casks.

Chapter 2, Section 2.1.3.3, contains detailed descriptions of the transportation scenarios and implementing alternatives in Nevada. Sections 6.3.1 through 6.3.3 discuss potential impacts for the three Nevada transportation scenarios. Section 6.3.1 discusses potential environmental impacts that could occur in Nevada for the national mostly legal-weight truck scenario. Section 6.3.2 discusses potential environmental impacts for each of the five Nevada rail transportation implementing alternatives, including those from the construction and operation of a branch rail line, and the impacts of 1,079 legal-weight truck shipments over 24 years. Section 6.3.3 discusses potential impacts of each of the five Nevada heavy-haul truck transportation implementing alternatives, including upgrading Nevada highways, the associated activities of constructing and operating an intermodal transfer station, and the impacts of 1,079 legal-weight truck shipments over the 24 years of operations. Appendix J, Section J.3.6, presents an analysis of impacts of transporting people and materials that would be necessary to implement the Proposed Action. Appendix J also discusses the methods used to analyze impacts for the 12 resource areas.

The EIS analysis evaluated potential impacts that would occur in Nevada from the construction and operation of a branch rail line or from upgrades to highways and construction and operation of an intermodal transfer station for the following environmental resource areas: land use and ownership; air quality; hydrology (surface water and groundwater); biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; waste management; and environmental justice. The following paragraphs describe the methods used to evaluate potential impacts to these resource areas for each of the three Nevada transportation scenarios—legal-weight truck, rail, and heavy-haul truck—and their applicable implementing alternatives.

Tables 6-16 and 6-17 compare the impacts of the Nevada rail and heavy-haul implementing alternatives, respectively, along with the impacts in Nevada under the mostly legal-weight truck scenario. The comparisons in the tables show that potential health and safety impacts to the public and workers in Nevada would be small for both the mostly legal-weight truck and mostly rail transportation scenarios. In addition, the tables illustrate that impacts would be similar among the 10 rail and heavy-haul truck implementing alternatives. The radiological impacts of incident-free transportation in the State for any of the 10 implementing alternatives or for the mostly legal-weight truck scenario would be small for both the public and workers. The radiological impact from 24 years of transportation would range from 0.0009 to 0.17 latent cancer fatality in the population along routes. The radiological impact to transportation workers from 24 years of operations would range from 0.28 to 0.75 latent cancer fatality for the mostly rail scenario with a Valley Modified Corridor branch rail line and the mostly legal-weight truck scenario, respectively.

As many as 5 latent cancer fatalities could occur from a maximum reasonably foreseeable accident involving a rail shipment. Less than 1 (0.5) latent cancer fatality would occur as the result of a severe truck accident with a similar probability. These accidents would have a chance of occurring nationally of less than 3 in 10 million per year. Because only a small part of each national route is in Nevada, the rate of occurrence in the State would be much less than that nationally. Accidents that would be more likely would have lesser consequences.

Traffic fatalities in Nevada and fatalities caused by the effects of vehicle emissions would be greater for the mostly rail transportation scenario than for the mostly legal-weight truck scenario. The estimate of

Table 6-16. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 1 of 2).

Impact	Mostly rail with branch rail: Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Mostly legal-weight truck
Corridor length (kilometers)	512 - 553	514 - 544	344 - 382	181 - 204	159 - 163	230 - 270
Land use and ownership						
Disturbed land (square kilometers)[a]	18 - 20	19 - 20	13 - 14	9.2 - 10	5 - 5.2	0
Private land (square kilometers)	0.9 - 2.5	7.3 - 15	0.8 - 1.1	0.1 - 3.5	0 - 0.18	0
Nellis Air Force Range land (square kilometers)	0 - 11	0 - 11	22	0	3.6 - 7.5	0
Tribal	0 - 1.6	0 - 1.6	0	0	0	0
Air quality						
PM_{10} and carbon monoxide (construction and operations)	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - branch rail line not a significant source of pollution	Clark County is in nonattainment of air quality standards for PM_{10} - branch rail line construction could be a significant source of pollution[b]	Not a significant source of pollution
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Surface water resources along route	5	6	3	0	0	NA[d]
Flood zones	9	11	At least 3	7	2	NA
Groundwater						
Water use (acre-feet)[c]	710	660	480	410	320	0
Water use (number of wells)	64	67	43	23	20	0
Biological resources and soils	Low	Low	Low	Low	Low	Very low
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological or historical resources. Route passes close to the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Moderate	Low	Moderate	Moderate	Moderate	Low
Utilities and resources						
Diesel (million liters)[e]	45	41	36	30	14	Very low
Gasoline (thousand liters)	940	840	680	570	280	
Steel (thousand metric tons)[f]	78	75	52	29	23	0
Concrete (thousand metric tons)[g]	460	420	310	170	130	0

Table 6-16. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 2 of 2).

Impact	Mostly rail with branch rail: Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Mostly legal-weight truck
Aesthetics	Very low	Very low	Very low	Potential small area of conflict	Very low	None
Socioeconomics						
New jobs (percent of workforce in affected counties	840 (< 1% - 3.2%)	780 (< 1%)	650 (<1% - 2.3%)	530 (< 1%)	250 (< 1%)	Very low
Peak real disposable income (million dollars)	24	21	19	15	7	Very low
Peak incremental Gross Regional Product (million dollars)	40	36	31	26	13	Very low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Very low
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	220	200	180	150	110	NA
Lost workday cases	110	100	90	80	60	NA
Fatalities	0.43	0.41	0.38	0.3	0.25	NA
Collective dose (person-rem [LCFs])						
Workers	850 [0.34]	980 [0.39]	740 [0.3]	760 [0.3]	710 [0.28]	1,900 [0.75]
Public	19 [0.009]	38 [0.019]	50 [0.025]	130 [0.06]	23 [0.012]	340 [0.17]
Fatalities from vehicle emissions	0.25	0.25	0.2	0.23	0.13	0.086
Accident impacts, nonradiological traffic						
Construction and operations workforce	1.9	1.8	1.5	1.2	0.9	NA
SNF[h] and HLW[i] shipping	0.07	0.09	0.05	0.06	0.05	0.49
Accident impacts, radiological						
Radiological accident risk						
Person-rem	0.002	0.003	0.002	0.007	0.002	0.053
Latent cancer fatalities	0.0000009	0.0000013	0.0000009	0.0000036	0.000001	0.000026
Maximum reasonably foreseeable accident						
Maximally exposed individual (rem)	29	29	29	29	29	3
Individual latent cancer fatality probability	0.014	0.014	0.014	0.014	0.014	0.0015
Collective dose (person-rem)	9,900	9,900	9,900	9,900	9,900	1,100
Latent cancer fatalities	4.9	4.9	4.9	4.9	4.9	0.55

a. Convert square kilometers to acres, multiply by 247.1.
b. Conformity determination could be required (see Chapter 6, Sections 6.3.2.1 and 6.3.2.2.5).
c. To convert acre-feet to gallons, multiply by 325,850.1.
d. NA = not applicable.
e. To convert liters to gallons, multiply by 0.26418.
f. To convert metric tons to tons, multiply by 1.1023.
g. To convert cubic feet to cubic meters, multiply by 0.028317.
h. SNF = spent nuclear fuel.
i. HLW = high-level radioactive waste.

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Table 6-17. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 1 of 3).

Impact	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
	Mostly rail with heavy-haul truck					
Corridor length (kilometers)	530	280	380	190	180	230 - 270
Land use and ownership						
Disturbed land (square kilometers)[a]	3.4	1.3	2.1	0.63	0.63	0
Private land (square kilometers)	0	0	0	0	0	0
Nellis Air Force Range land (square kilometers)	0	0	0	0	0	0
Air quality						
PM_{10} and carbon monoxide (construction and operations)	Areas in attainment of air quality standards - not a significant source of pollution	Areas in attainment of air quality standards - not a significant source of pollution	Clark County is in nonattainment of air quality standards - heavy-haul route construction could be a significant source of pollution[b]	Except in Clark County, areas in attainment of air quality standards - not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - not a significant source of pollution	Not a significant source of pollution
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Groundwater						
Water use (acre-feet)c	100	60	44	8	8	0
Water use (number of wells)	16	5	7	Truck water	Truck water	0
Biological resources and soils	Low	Low	Low	Low	Low	Very low
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources; route near Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; route passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; IMT[d] and route near the Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Low	Low	Low	Low	Low	Low
Utilities and resources						
Diesel (million liters)[e]	13	4.7	5.5	1.7	1.6	Very low
Steel (metric tons)[f]	49	14	21	2.3	2.3	0
Concrete (thousand metric tons)[g]	1.8	0.5	0.8	0.1	0.1	0
Aesthetics	Some potential near Caliente	Some potential near Caliente	Some potential near Caliente	Very low	Very low	None

Table 6-17. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 2 of 3).

	Mostly rail with heavy-haul truck					
Impact	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Socioeconomics						
New jobs (percent of workforce in affected counties)	860 (< 1% - 3.3%)	750 (< 1% - 4.9%)	590 - 1,980 (< 1% - 3.3%)	630 - 3,050 (< 1%)	490 - 1,880 (< 1%)	Very low
Peak real disposable personal income (million dollars)	27	22	19 - 65	21 - 97	16 - 62	Very low
Peak incremental Gross Regional Product (million dollars)	45	40	33 - 104	36 - 153	29 - 100	Very low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Very low
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	310	270	260	150	150	NA[h]
Lost workday cases	160	140	140	80	80	NA
Fatalities	0.72	0.68	0.63	0.37	0.37	NA
Collective dose (person-rem [LCFs])						
Workers	1,600 [0.65]	1,200 [0.50]	1,400 [0.56]	1,200 [0.48]	1,100 [0.46]	1,900 [0.75]
Public	76 [0.038]	61 [0.030]	220 [0.11]	300 [0.15]	160 [0.08]	340 [0.17]
Fatalities from vehicle emissions	0.47	0.32	0.46	0.42	0.29	0.086
Accident impacts, nonradiological traffic						
Construction and operations workforce	3.5	2.4	3.0	1.7	1.7	NA
SNF[i] and HLW[j] shipping	0.6	0.33	0.43	0.25	0.23	0.49
Accident impacts, radiological						
Radiological accident risk						
Person-rem	0.01	0.002	0.056	0.12	0.056	0.053
Latent cancer fatalities	0.0000051	0.000001	0.000028	0.00006	0.000028	0.000026

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Table 6-17. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 3 of 3).

Impact	Mostly rail with heavy-haul truck: Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Maximum reasonably foreseeable accident						
Maximally exposed individual (rem)	29	29	29	29	29	3
Individual latent cancer fatality probability	0.014	0.014	0.014	0.014	0.014	0.0015
Collective dose (person-rem)	9,900	9,900	9,900	9,900	9,900	1,100
Latent cancer fatalities	4.9	4.9	4.9	4.9	4.9	0.55

a. To convert square kilometers to acres, multiply by 247.1.
b. Conformity determination could be required (see Chapter 6, Sections 6.3.3.1 and 6.3.3.2.3).
c. To convert acre-feet to gallons, multiply by 325,850.1.
d. IMT = intermodal transfer.
e. To convert liters to gallons, multiply by 0.26418.
f. To convert metric tons to tons, multiply by 1.1023.
g. To convert cubic feet to cubic meters, multiply by 0.028317.
h. NA = not applicable.
i. SNF = spent nuclear fuel.
j. HLW = high-level radioactive waste.

traffic facilities includes those that could occur when workers associated with highway or railroad construction commute to and from their work site. The estimates also include traffic fatalities that could result from highway accidents in delivering construction materials used to construct a branch rail line or upgrade highways and construct an intermodal transfer station. Construction and operations activities to transport spent nuclear fuel and high-level radioactive waste in Nevada could result in less than 1 to 5 traffic fatalities (0.5 or a 50 percent chance of 1 fatality to about 4.6). The fewest number of traffic fatalities would occur under the mostly legal-weight truck scenario, principally because the scenario would not require workers associated with construction and operations for Nevada rail implementing alternatives.

Because the trucks would use existing highways and be less than 1 percent of other commercial truck traffic on these highways, measurable impacts would not occur in environmental resource areas other than health and safety in Nevada for mostly legal-weight truck transportation. In contrast, the mostly rail scenario, or any other mix of rail and truck transportation that included a large amount of rail transportation, would require DOE to construct and operate a branch rail line in one of the five candidate rail corridors or construct and operate an intermodal transfer station and work with the State to upgrade highways to use one of the candidate routes for heavy-haul trucks. As a consequence, for the DOE-preferred mostly rail scenario, there would be impacts in Nevada to land use, air quality, hydrological resources, biological resources and soils, cultural resources, socioeconomics, aesthetics, noise and vibration, and waste management. Because it would require acquisition of a large area of land in the State, disturbance of land areas not previously disturbed, and the greatest amount of construction activity, construction of a branch rail line would have the potential to cause greater impacts in all resource areas except health and safety than would construction of an intermodal transfer station and highway upgrades. However, all five of the candidate rail corridors pass through sparsely populated or uninhabited areas of Nevada. Therefore, trains on a branch rail line after construction would have less day-to-day impact on daily life in communities than would heavy-haul trucks, which would share highways with other vehicles. Operational impacts (encompassing those impacts that would occur after construction of a branch rail line or highway upgrade for heavy-haul trucks) would be small in all resource areas for all ten of the rail and heavy-haul truck implementing alternatives.

In general, the longest rail corridor (Caliente) would have the largest potential for impacts, but there are exceptions. For example, construction of a branch rail line in the Valley Modified Corridor, which is the shortest of the five, could affect the Clean Air Act attainment objectives of Clark County for PM_{10} and carbon monoxide, for which the Las Vegas Valley air basin is currently in nonattainment. In addition, both the Jean and Valley Modified Corridors pass through desert tortoise habitat over their entire length and over a distance greater than the three longer corridors. The Wilson Pass Option of the Jean Corridor would require construction of a branch rail line in areas classified by the Bureau of Land Management as Class II for visual resource management. Construction and use of a branch rail line in these areas could be in conflict with Bureau Visual Resource Management guidelines. All five corridors and the Caliente/Chalk Mountain heavy-haul route have potential land-use conflicts at some points along their lengths. The ability of DOE to avoid or mitigate these conflicts varies among the implementing alternatives.

Construction or upgrading of the longest heavy-haul route (Caliente) would lead to the greatest potential for impacts, with some exceptions. For example, although most impacts of using an Apex/Dry Lake heavy-haul truck implementing alternative would be less than those of using a Caliente heavy-haul truck implementing alternative, the potential for impacts to air quality in the Las Vegas Valley air basin and impacts on traffic flow in the Las Vegas metropolitan area are greater for the Apex/Dry Lake route than for the Caliente route. In addition, socioeconomic impacts in Lincoln County, although small, would be greatest for construction and use of a Caliente/Chalk Mountain heavy-haul route. Furthermore, while health and safety impacts in small communities in Nevada, while small, would be greatest for a Caliente heavy-haul route, the shortest route would use the Las Vegas Beltway, which would pass through a highly populated commercial and residential area of North Las Vegas.

Each rail corridor and heavy-haul route could pass near or through areas having high percentages of minority or low-income populations. However, DOE has determined that there would be no environmental justice concerns for any of the proposed routes for heavy-haul trucks or corridors for a potential branch rail line because no potential impact to these populations would be both high and adverse.

LAND USE AND OWNERSHIP

DOE determined that information useful for an evaluation of land-use and ownership impacts should identify the current ownership of the land that its activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts was defined as land areas that would be disturbed or whose ownership or use would change as a result of the construction and use of a branch rail line, intermodal transfer station, midroute stopover for heavy-haul trucks, and an alternative truck route near Beatty, Nevada.

AIR QUALITY

The evaluation of impacts to air quality considered potential emissions of criteria pollutants [nitrogen dioxide, sulfur dioxide, carbon monoxide, particulates with aerodynamic diameters of less than 10 micrometers (PM_{10})], lead, and ozone, the percentage of applicable standards and limits, and the potential for releases of these pollutants in the Las Vegas Valley. The region of influence for the air quality analysis included (1) the Las Vegas Valley for implementing alternatives that could contribute to the levels of carbon monoxide and PM_{10}, which are already in nonattainment of Clean Air Act standards (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54), during the construction and operation of a branch rail line or highway for heavy-haul trucks, and (2) the atmosphere in the vicinity of the sources of criteria pollutants that transportation-related construction and operation activities would emit. The evaluation included a conformity review for emissions to the Las Vegas Valley air basin that would result from the Proposed Action.

HYDROLOGY

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding or dredging and filling actions to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction activities, areas that would be affected by permanent changes in flow, and areas downstream of construction.

The analysis addressed the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability for use for construction, the potential for changing flow patterns and, if available, the potential that such use would affect other users. The region of influence for this analysis included groundwater reservoirs.

BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for conflicts with areas of critical environmental concern; special status species (plants and animals), including their habitats; and jurisdictional waters of the United States, including wetlands and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of big game animals. The region of influence for this analysis included the following:

- Habitat, including jurisdictional waters of the United States, including wetlands and riparian areas

- Migratory ranges of big game animals that could be affected by the presence of a branch rail line

DOE identified known biological resources within 5 kilometers (3 miles) of each rail corridor or variation. Resources were categorized based on proximity to the railroad—that is, inside the 400-meter-(0.25-mile)-wide corridor or outside the corridor but within 5 kilometers of the railroad. A railroad would be unlikely to influence some resources outside the corridor, such as populations of sensitive plant species or springs. It could influence other resources, especially those involving large game animals, horses, or burros, because they could traverse the distance to the railroad easily.

DOE identified soils classified as Easily Erodible, Prime Farmland, Shrink-Swell, Unstable Fill, or Blowing Soil along each route. No Prime Farmland was identified for any route. Although these soil characteristics would principally influence construction, they could influence the amount of land disturbed inside and outside the corridor and the local environment during construction, such as temporary increases in sediment loads in nearby waterways or springs, or entrainment of blowing soil.

The analysis assessed soil impacts to determine the potential to increase erosion rates by water or wind. The region of influence for the analysis of soil impacts included areas where construction would take place and downwind or downgradient areas that would be affected by eroded soil.

CULTURAL RESOURCES

The evaluation of impacts on cultural resources considered the potential for disrupting, or modifying the character of, archaeological or historic sites, artifacts, and other cultural resources, such as traditional cultural properties and cultural landscapes.

The specific region of influence for the *direct impact* analysis included the lands in the 400-meter (0.25-mile)-wide rail corridors, lands within existing highway rights-of-way that would be upgraded for heavy-haul truck use, and sites where an intermodal transfer station could be constructed and operated. The analysis assessed the potential for impacts to areas adjacent to a proposed rail corridor, such as landscapes traditional to American Indians or other historic cultural landscapes.

OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The analysis of impacts to occupational and public health and safety from transportation-related activities in Nevada used the same methods, assumptions, attributes, and regions of influence used for the analysis of impacts of national transportation of spent nuclear fuel and high-level radioactive waste. However, it used the rail and highway accident rates reported for the State of Nevada (DIRS 103455-Saricks and Tompkins 1999, Table 4). The analysis also considered the daily average nonresident population in the Las Vegas metropolitan area for routes that pass through the Las Vegas metropolitan area.

In addition, the analysis included potential impacts from industrial hazards to Nevada workers from constructing and operating a branch rail line, upgrading highways for use by heavy-haul trucks, and constructing and operating an intermodal transfer station. The region of influence for the analysis included branch rail line and highway construction work sites and highways that workers and other construction-related vehicle traffic would use. The analysis considered potential radiological impacts from intermodal transfer station operations.

In addition, the analysis estimated doses to potential maximally exposed individuals in Nevada communities through which truck or rail shipments could travel. Appendix J, Section J.1.3.2.2 discusses the basis for these estimates. The health and safety portions of Sections 6.3.2.1 and 6.3.3.1 describe the potential impacts to maximally exposed individuals in Nevada.

SOCIOECONOMICS

The analysis of transportation-related socioeconomic impacts considered changes in annual levels of employment, population, housing, and schools, in addition to the economic measures of real disposable income, Gross Regional Product, and state and local government expenditures based on analyses DOE conducted using the Regional Economic Models, Inc. model (DIRS 148193-REMI 1999, all). The region of influence for the analysis included Clark, Lincoln, and Nye Counties. The other Nevada counties were included collectively in the Rest of Nevada analysis. The analysis considered impacts that would occur during construction and operation of the various transportation implementing alternatives.

The analysis expressed socioeconomic impacts as a percentage change, which it calculated by comparing the derived increase or decrease in a given socioeconomic parameter to the estimated baseline value for:

- Each county in the region of influence (Clark, Nye, and Lincoln), the Rest of Nevada, and the State of Nevada.
- The year.
- Economic measures (employment, population, real disposable income, Gross Regional Product, and State and local government spending).

Chapter 3, Section 3.1.7 lists the baseline values of each economic measure.

DOE has described the socioeconomic measures on a peak year basis for constructing a branch rail line, upgrading of highways, or constructing an intermodal transfer station and on an average basis for transportation operations. The Department used peak values and their impacts for construction because impacts would tend to be concentrated in 1 or 2 years. DOE used average values for the period of transportation operations as a more meaningful presentation of the data. Impacts, as a percentage of the baselines, would tend to be relatively stable over the 24 years of transportation operations for the Proposed Action.

In light of public comments received on the Draft EIS concerning perception-based and stigma-related impacts, DOE examined relevant studies and literature on perceived risk and stigmatization of communities to determine whether the state of the science in predicting future behavior based on perceptions had advanced sufficiently since scoping to allow DOE to quantify the impact of public risk perception on economic development or property values in potentially affected communities. Of particular interest were those scientific and social studies carried out in the past few years that directly relate to either Yucca Mountain or to DOE actions such as the transportation of foreign research reactor spent nuclear fuel. DOE also reevaluated the conclusions of previous literature reviews such as those conducted by the Nuclear Waste Technical Review Board and the State of Nevada, among others. DOE has concluded that:

- While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable methods whereby such impacts could be predicted with any degree of certainty
- Much of the uncertainty is irreducible, and
- Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

While stigmatization of southern Nevada can be envisioned under some scenarios, it is not inevitable or numerically predictable. Any such stigmatization would likely be an aftereffect of unpredictable future events, such as serious accidents, which may not occur. As a consequence, DOE did not attempt to quantify any potential for impacts from risk perceptions or stigma in this Final EIS. Chapter 2, Section 2.5.4 contains further detail.

NOISE AND VIBRATION

Nevada does not have a noise code, so the analysis used daytime and nighttime noise standards adopted by Washington State (Washington Administrative Code 173-58-040 to 173-60-040) for residential and commercial areas as benchmarks and for establishing the region of influence for potential impacts. DOE used these benchmarks [60 dBA for residential use (nighttime reduction to 50 dBA), 65 dBA for light commercial, and 70 dBA for industrial zones] to evaluate the impacts of noise from construction and operational activities for receptors in the region of influence near transportation facilities and corridors. Noise levels in areas and communities outside the region of influence were not addressed. To analyze the potential for community noise impacts, DOE established the region of influence as 1,000 meters (about 0.63 mile) based on the residential nighttime benchmark. This is the approximate distance from a railroad or highway at which the sound levels from passing trains or traffic would fall below 50 dBA. The distances for noise levels from a railroad to fall below 50 dBA (nighttime residential noise standard) and 60 dBA (daytime residential guideline) are 1,000 meters and 450 meters (about 0.25 mile), respectively.

DOE also defined a region of influence for locations where there would be a potential for impacts to solitude. These locations would include sites of special interest to Native Americans, where DOE assumes a sound level of 20 dBA would be necessary for solitude. This distance from passing trains or traffic would be about 6,000 meters (3.7 miles). To provide some perspective on the potential severity of noise impacts, the analysis estimated the population within 2 kilometers (about 1.3 miles) of each proposed rail corridor and heavy-haul truck route.

In addition to noise standards, the analysis assessed the frequency at which transportation noise from construction or operation of a transportation route could lead to complaints. It considered the proximity of transportation routes to centers of population and the frequency of shipments.

The analysis also considered potential effects of ground vibration from trains and heavy-haul trucks. In general, the operation of trains and trucks does not create vibration levels of an intensity that can damage most buildings unless they are very close to the rail line or highway (DIRS 155547-HMMH 1995, p. 8-3). Because trucks run on inflated tires, ground vibration is greatly reduced and the only situation that can produce potentially damaging ground vibration occurs when the vehicle strikes a bump or hole in the road. The intensity of the vibration depends on the size of the bump, speed and weight of the vehicle, and geology. Ground vibration can be disturbing to people, particularly at night, and it can adversely affect vibration-sensitive activities such as semiconductor manufacturing, operation of electron microscopes, and other activities. The U.S. Department of Transportation has proposed critical distances for the evaluation of ground vibration (DIRS 155547-HMMH 1995, pp. 9-4 and 8-3). These are expressed in feet and are based on the *decibel* scale for vibration (VdB) of root-mean-square (in relation to a microinch per second base). (A microinch is one-millionth of an inch or 0.0000025 centimeter; this measurement is used in applications that require extremely tight tolerances.) The endpoint for sensitive buildings is 65 VdB and the corresponding critical distance is 600 feet (about 180 meters). For human annoyance, the critical distance is based on 72 VdB and corresponds to 200 feet (about 61 meters). The estimated critical distance for structural damage due to the operation of unit coal trains is 100 meters (about 330 feet) based on a peak particle velocity measurement of 0.1 inch per second. Trains traveling to Yucca Mountain would include two locomotives and probably no more than 10 cars. The U.S. Department of Transportation (DIRS 155547-HMMH 1995, all) has proposed a structure protection criterion of

0.12-inch-per-second peak particle velocity. A corresponding region of influence is 100 meters (about 330 feet). High levels of ground vibration can be managed in sensitive areas by reducing the speed of the trains, a factor that usually occurs for safety purposes. Most of the candidate rail corridors to Yucca Mountain are in open or isolated areas with few structures; as a consequence, the chance of building damage from the operation of trains would be very small.

The analysis of impacts on biological resources considered the effects of environmental noise from trains and trucks on animals. There are no standards or regulatory measures for such impacts.

AESTHETICS

The analysis of potential impacts on aesthetic resources considered Bureau of Land Management ratings for land areas (DIRS 101505-BLM 1986, all). The regions of influence used in the analysis included the landscapes along the potential rail corridors and highway routes and near possible locations of intermodal transfer stations with aesthetic quality that construction and operations could affect.

The analysis of impacts was based on visual sensitivity ratings of viewsheds in Nevada and the Bureau of Land Management Visual Resource Management System objectives. It established ratings for scenery based on the number and types of users, public interest in the area, and adjacent land uses. The ratings are based on the scenic quality classes in the Bureau of Land Management Visual Resource Management System (DIRS 101505-BLM 1986, all).

UTILITIES, ENERGY, AND MATERIALS

The attributes used to assess impacts to utilities, energy, and materials included the requirements for electric power, fossil fuel for construction, and key consumable construction materials. The analysis compared needs to available capacity. The region of influence included the local, regional, and national supply infrastructure that would have to satisfy the needs.

WASTE MANAGEMENT

Evaluations of impacts of waste management considered the nonhazardous industrial, sanitary, hazardous, and low-level radioactive wastes that the Proposed Action would generate. The region of influence included construction areas and camps and facilities that would support transportation operations such as locomotive and railcar maintenance facilities.

ENVIRONMENTAL JUSTICE

DOE performs environmental justice analyses to identify whether any high and adverse impacts would fall disproportionately on minority and low-income populations. There would be a potential for environmental justice concerns if the following occurred:

- *Disproportionately high and adverse human health effects to minority or low-income populations:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. Disproportionately high and adverse human health effects occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (DIRS 103162-CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (DIRS 103162-CEQ 1997, all).

The approach to environmental justice analysis first brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that could affect human health or the environment. The environmental justice approach considers assessments from these disciplines that identify potential impacts on the general population. Second, based on available information, the approach assesses if there are unique exposure pathways, sensitivities, or cultural practices that would result in high and adverse impacts on minority and low-income populations. If potential impacts identified under either assessment would be high and adverse, the approach then compares the impacts on minority and low-income populations to those on the general population to determine if any high and adverse impacts would fall disproportionately on minority and low-income populations. In other words, if high and adverse impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, disproportionately high and adverse impacts would be unlikely. In making these determinations, DOE considers geographic areas that contain high percentages of minority or low-income populations as reported by the Bureau of the Census.

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprising a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population; for this EIS, a minority population is one in which the percent of the total population comprising of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (DIRS 103162-CEQ 1997, all). Nevada had a minority population of 34.8 percent in 2000 (see Chapter 3, Section 3.1.13 for a discussion of population information). For this EIS, therefore, one focus of the environmental justice analysis is the potential for transportation-related activities of the Proposed Action to have disproportionately high and adverse impacts on the populations in census tracts in the region of influence (principally in Clark, Nye, and Lincoln Counties) with a minority population of 44.8 percent or higher.

Nevada had a low-income population of 10 percent in 1990. Using the approach described in the preceding paragraph for minority populations, a low-income population is one in which 20 percent or more of the persons in a census block group live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements (DIRS 152051-OMB 1999, all; DIRS 103127-Bureau of the Census 1999, pp. 114 and 116). Therefore, the second focus of the environmental justice analysis for this EIS is the potential for the Proposed Action to have disproportionately high and adverse impacts on the populations in census block groups with a low-income population of 20 percent or higher.

In response to comments, DOE has updated and refined available information to determine whether the Draft EIS overlooked any unique exposure pathways or unique resource uses that could create opportunities for disproportionately high and adverse impacts to minority and low-income populations, even though the impacts to the general population would not be high and adverse. The Department identified and analyzed several unique pathways and resources (for example, cultural and aesthetic resources, land use, air quality, and noise), but none revealed a potential for disproportionately high and adverse impacts (see Section 6.3 and Appendix J, Section J.3). DOE has updated and refined information germane to environmental justice analysis, including additional and more detailed mapping of minority populations (see Appendix J, Section J.3.1.2).

Section 6.3.4 describes the results of the analysis for the Nevada transportation scenarios.

6.3.1 IMPACTS OF THE NEVADA MOSTLY LEGAL-WEIGHT TRUCK TRANSPORTATION SCENARIO

Legal-weight truck shipments in Nevada of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use existing highways (see Figure 6-13) and would be a very small fraction of the total traffic [less than 600,000 kilometers (370,000 miles) per year for legal-weight truck shipments in Nevada in comparison to an estimated 1.2 billion kilometers (750 million miles) per year of commercial vehicle traffic on I-15 and U.S. Highway 95 in southern Nevada]. As a consequence, impacts to land use; hydrology; biological resources; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would not be large.

Because of a U.S. Fish and Wildlife Service concern about populations of desert tortoises and Clark County concern about air quality in the Las Vegas air basin, this section addresses the potential for impacts to this threatened species and to the quality of air in the basin. This section focuses on impacts to occupational and public health and safety in Nevada. Section 6.3.4 contains a consolidated discussion of the potential for transportation activities to cause environmental justice concerns.

6.3.1.1 Impacts to Air Quality

DOE conducted a conformity review using the guidance in DIRS 155566-DOE (2000, all) for the transportation activities of the mostly legal-weight truck scenario. The Las Vegas air basin is in nonattainment status for carbon monoxide, which is largely a result of vehicle emissions (DIRS 156706-Clark County 2000, Appendix A, Table 1-3). The review determined that during repository-related operations, when maximum emissions would occur, the transportation of employees, materials, and supplies, and the transportation of spent nuclear fuel and high-level radioactive waste would not exceed the General Conformity threshold levels for carbon monoxide. Total emissions would be 63 metric tons (69 tons) per year (69 percent of the threshold) and 0.25 metric ton (0.28 ton) per day (0.07 percent of the 2000 daily carbon-monoxide levels in the Las Vegas air basin) (DIRS 156706-Clark County 2000, Appendix A, Table 1-3).

The DIRS 155112-Berger (2000, p. 55) estimate for transportation of radioactive materials only for the legal-weight truck transport for 2010 is 0.27 metric ton (0.03 ton) per day. This estimate includes traffic congestion emissions. Although DOE believes the estimate is high, a value of 0.03 ton per day, 5 days per week, 50 weeks per year, would result in about 6.8 metric tons (7.5 tons) of carbon monoxide per year, which is less than 10 percent of the threshold.

6.3.1.2 Impacts to Biological Resources

Legal-weight truck shipments in Nevada to a Yucca Mountain Repository would involve travel over highways that cross desert tortoise habitat, but none of the routes would cross habitat that the U.S. Fish and Wildlife Service has designated as critical for the recovery of this threatened species (50 CFR 17.95). Over the course of 24 years of operations under the Proposed Action and 53,000 shipments, vehicles probably would kill individual desert tortoises. However, under this scenario legal-weight trucks would contribute only about 1 percent to the daily traffic of vehicles to and from the repository site and only about 0.15 percent of all commercial truck traffic along I-15 and U.S. 95 in southern Nevada. Thus, any desert tortoises killed by trucks transporting spent nuclear fuel or high-level radioactive waste probably would be only a small fraction of all desert tortoises killed on highways. Loss of individual desert tortoises due to legal-weight truck shipments would not be a large threat to the conservation of this species. DOE is engaged in consultation with the U.S. Fish and Wildlife Service to ensure protection of desert tortoises and other biological resources.

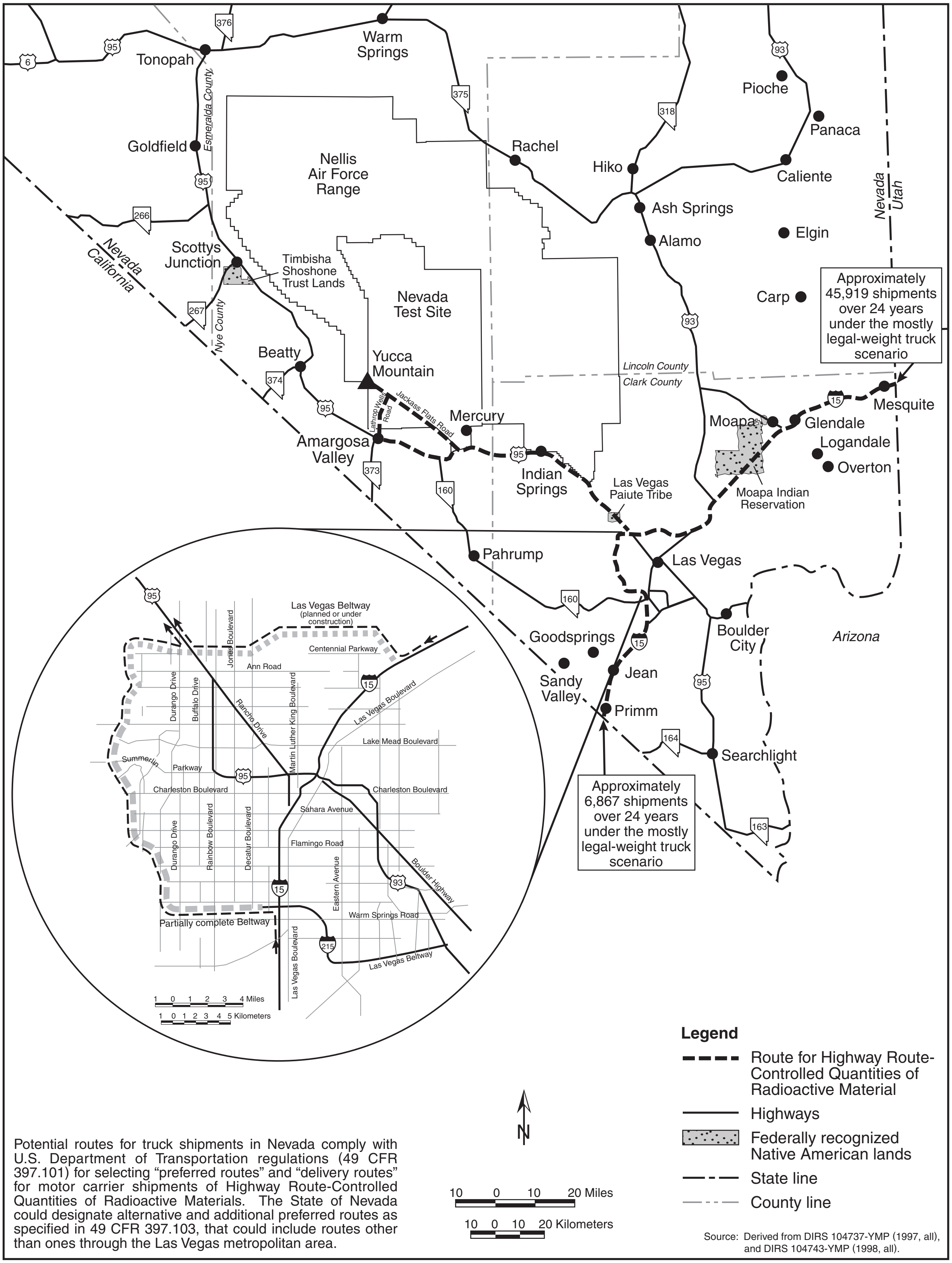

Figure 6-13. Potential Nevada routes for legal-weight trucks and estimated number of shipments.

6.3.1.3 Impacts to Occupational and Public Health and Safety

6.3.1.3.1 *Impacts from Incident-Free Transportation*

This section addresses radiological impacts to populations and maximally exposed individuals in Nevada from the incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly legal-weight truck scenario. It includes potential impacts from exposure to vehicle emissions in Nevada.

Incident-Free Radiological Impacts to Populations. Table 6-18 lists the incident-free population dose and radiological impacts for the Nevada mostly legal-weight truck scenario. The impacts include those from the shipment of naval spent nuclear fuel by rail in Nevada to an intermodal transfer station, heavy-haul transfer activities, and subsequent heavy-haul truck transportation to the proposed repository. The analysis included the radiological impacts of intermodal transfer operations for naval spent nuclear fuel shipments. Occupational impacts would include estimated radiological exposures to security escorts for legal-weight truck, rail, and heavy-haul truck shipments. The estimated radiological impacts would be 0.75 latent cancer fatality for workers and 0.18 latent cancer fatality for members of the public over the 24 years of operation.

Table 6-18. Population doses and radiological health impacts from incident-free transportation for Nevada mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	1,900	18	1,900
Estimated LCFs[d]	0.75	0.01	0.75
Public			
Collective dose (person-rem)	340	10	350
Estimated LCFs	0.17	0.005	0.18

a. Impacts are totals for shipments over 24 years.
b. Includes impacts at intermodal transfer stations.
c. Totals might differ from sums of values due to rounding.
d. LCF = latent cancer fatality.

DOE based estimated impacts of legal-weight truck shipments in Nevada on routes identified for analysis in accordance with requirements in U.S. Department of Transportation regulations (49 CFR 397.101). As required by those regulations, and because the Las Vegas Beltway will be part of the Interstate Highway System, DOE assumed its use to avoid travel through the heavily traveled center of Las Vegas. In addition, DOE analyzed the potential impacts of using other routes that the State of Nevada has studied and of routing shipments through the Interstate 15-U.S. 95 interchange (the "*Spaghetti Bowl*"). Appendix J, Section J.3.1.3 discusses the results of these analyses, which range from 83 to 490 person-rem (0.04 to 0.25 latent cancer fatality in the affected population) for Nevada populations.

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-19 lists estimates of dose and radiological impacts for maximally exposed individuals for the Nevada legal-weight truck scenario from 24 years of shipment activity. The analysis used the assumptions presented in Section 6.2.1 and Appendix J.

The analysis assumed the annual dose to state inspectors who conducted frequent inspections of shipments of spent nuclear fuel and high-level radioactive waste would be limited to 2 rem.

The analysis estimated that a maximally exposed individual at a service station would receive 2.4 person-rem over 24 years under the legal-weight truck scenario. This estimate conservatively assumed the person would be exposed to 450 truck shipments each year for 24 years. For perspective, under the mostly legal-weight truck scenario, which assumes an average of 2,200 legal-weight truck shipments per

Table 6-19. Estimated doses and radiological health impacts to maximally exposed individuals during incident-free transportation for Nevada mostly legal-weight truck scenario.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member	48[c]	0.02
Inspector	48[c]	0.02
Railyard crew member	0.13	0.00005
Public		
Resident along route[d]	0.02	0.00001
Person in traffic jam[e]	0.016	0.000008
Person at service station[f]	2.4	0.0012
Resident near rail stop	0.009	0.000005

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Impacts are totals over 24 years.
c. Based on 2-rem-per-year dose limit (DIRS 156764-DOE 1999, Article 211).
d. This represents a Nevada resident approximately 11 meters (36 feet) from the highway. See Appendix J, Section J.1.3.2.2.
e. Person in a traffic is assumed to be exposed one time only.
f. Assumes the person works at the service station for all 24 years of repository operations. Mitigation would be required to reduce doses to members of the public to less than 100 millirem per year.

year, about 450 truck shipments would pass through the Mercury, Nevada, gate to the Nevada Test Site in 1,800 hours. A worker at a truck stop along the route to Mercury would work about 1,800 hours per year. Thus, if every shipment stopped at that truck stop, the maximum number of shipments the worker would be exposed to in a year would be 450. Appendix J, Section J.1.3.2.2, describes assumptions for estimating doses to maximally exposed individuals along routes in Nevada.

Impacts from Vehicle Emissions. There is potential for human health impacts to people in Nevada who would be exposed to pollutants emitted from vehicles transporting spent nuclear fuel and high-level radioactive waste, including escort vehicles. Table 6-20 lists the estimated number of vehicle emission-related fatalities from legal-weight trucks, a small number of heavy-haul trucks carrying naval spent nuclear fuel, escort vehicles, and rail locomotives under the mostly legal-weight truck scenario. Trucks would be the major contributors. Less than 1 (0.093) vehicle emission-related fatality would be likely.

Table 6-20. Population health impacts from vehicle emissions during incident-free transportation for Nevada mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Total
Vehicle emission-related fatalities	0.086	0.0069	0.093

a. Impacts are totals for shipments over 24 years.
b. Includes heavy-haul truck shipments in Nevada.

6.3.1.3.2 *Impacts from Accidents – Nevada Legal-Weight Truck Scenario*

This section discusses radiological impacts to populations and maximally exposed individuals in Nevada and the potential number of traffic accident fatalities from accidents during the transportation of spent nuclear fuel and high-level radioactive waste for the mostly legal-weight truck scenario. The analysis of accident impacts under this scenario includes impacts from accidents that would occur during the transportation of naval spent nuclear fuel by rail in Nevada to an intermodal transfer station and by heavy-haul truck to the repository. Section 6.3.3 discusses impacts to workers from industrial hazards during the operation of an intermodal transfer station for shipments of naval spent nuclear fuel.

Radiological Impacts from Accidents. The calculated collective radiological dose risk of accidents would be approximately 0.053 person-rem for the population in Nevada within 80 kilometers (50 miles) along the routes under the mostly legal-weight truck scenario. This calculated dose risk would be the total for 24 years of shipment operations. The radiological dose risk of accidents is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. A radiological dose risk of 0.05 person-rem would result in much less than 1 (0.000026) latent cancer fatality in the exposed population. The radiological risk from accidents would include impacts from approximately 53,000 legal-weight truck shipments and 300 naval spent nuclear fuel rail shipments. The accident risk for legal-weight truck shipments would account for essentially all of the population dose and radiological impacts. Because DOE would not build a branch rail line to the repository under this scenario, the accident risk for rail shipments of naval spent nuclear fuel includes risks from accidents that could occur during intermodal transfers from railcars to heavy-haul trucks and during heavy-haul transportation in Nevada. Section 6.3.3 provides additional information on heavy-haul truck implementing alternatives for transporting rail casks in Nevada.

Consequences of Maximum Reasonably Foreseeable Accident Scenarios. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario presented in Section 6.2.4.2.

MAXIMUM REASONABLY FORESEEABLE ACCIDENT SCENARIOS IN NEVADA

Maximum reasonably foreseeable accident scenarios analyzed for transportation in Nevada were the same as maximum reasonably foreseeable accident scenarios analyzed in Section 6.2.4.2 for national transportation. That is, the EIS analysis assumed that an accident determined to be reasonably foreseeable for national transportation could occur in Nevada. Because the distances traveled in Nevada would be much less than the total national travel to deliver spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, the likelihoods of these accident scenarios occurring in the State would be less than those for the rest of the Nation. The likelihoods of two of these accident scenarios occurring in national travel are reported in Section 6.2.4.2.

Impacts from Traffic Accidents. In Nevada, less than 1 (0.49) fatality from traffic accidents would be likely during the course of transporting spent nuclear fuel and high-level radioactive waste under the mostly legal-weight truck transportation scenario. This estimate includes traffic fatalities involving escort vehicles.

6.3.2 IMPACTS OF NEVADA RAIL TRANSPORTATION IMPLEMENTING ALTERNATIVES

This section describes the analysis of human health and safety and environmental impacts for five rail transportation implementing alternatives, each of which would use a newly constructed branch rail line in Nevada to transport spent nuclear fuel and high-level radioactive waste to the repository. The branch line would transport railcars carrying large shipping casks from a mainline railroad to the repository (loaded) and back (empty). DOE has identified five 400-meter (0.25-mile)-wide corridors of land—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified—for the possible construction and operation of the branch line (Figure 6-14). Chapter 2, Section 2.1.3.3.2 describes the corridors. Chapter 3, Section 3.2.2.1, discusses their affected environments.

Appendix J, Section J.3.1.2, contains additional information on the characteristics of possible variations of each corridor. Figure 6-14 shows these variations. Section 6.3.2.1 discusses impacts that would be common among the five possible corridors, and Section 6.3.2.2 discusses impacts that would be unique for each corridor.

DOE identified the five rail corridors through a process of screening the potential rail corridors it had studied in past years.

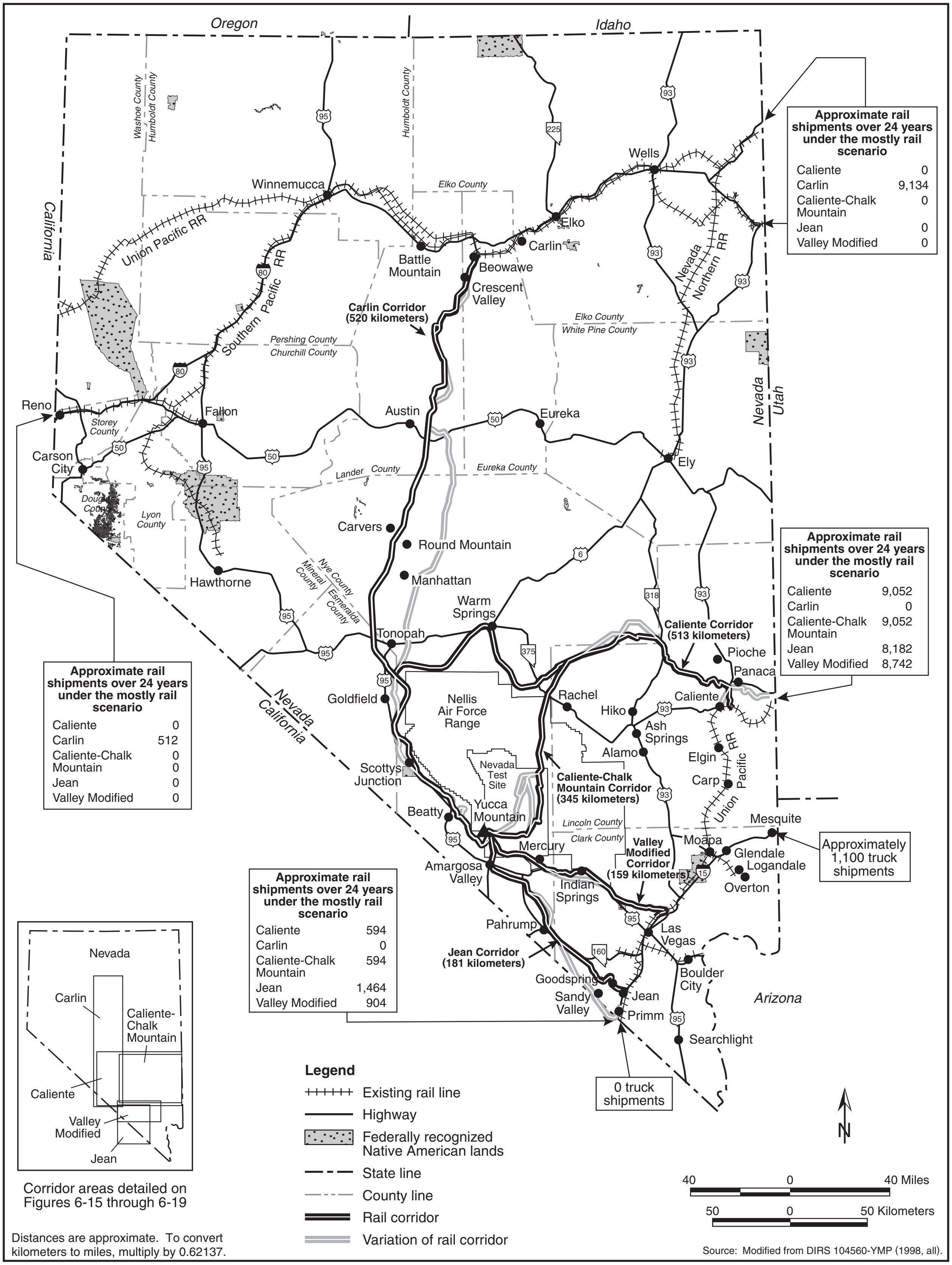

Figure 6-14. Potential Nevada rail routes to Yucca Mountain and estimated number of shipments for each route.

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- The *Feasibility Study for Transportation Facilities to Nevada Test Site* study (DIRS 104777-Holmes & Narver 1962, all) determined the technical and economic feasibility of constructing and operating a railroad from Las Vegas to Mercury.

- The *Preliminary Rail Access Study* (DIRS 104792-YMP 1990, all) identified 13 and evaluated 10 rail corridor options. This study recommended the Carlin, Caliente, and Jean Corridors for detailed evaluation.

- *The Nevada Railroad System: Physical, Operational, and Accident Characteristics* (DIRS 104735-YMP 1991, all) described the operational and physical characteristics of the current Nevada railroad system.

- The *High Speed Surface Transportation Between Las Vegas and the Nevada Test Site (NTS)* report (DIRS 104786-Cook 1994, all) explored the rationale for a potential high-speed rail corridor between Las Vegas and the Nevada Test Site to accommodate personnel.

- The *Nevada Potential Repository Preliminary Transportation Strategy, Study 1* (DIRS 104795-CRWMS M&O 1995, all), reevaluated 13 previously identified rail routes and evaluated a new route called the Valley Modified route. This study recommended four rail corridors for detailed evaluation—Caliente, Carlin, Jean, and Valley Modified corridors.

- The *Nevada Potential Repository Preliminary Transportation Strategy, Study 2* (DIRS 101214-CRWMS M&O 1996, all), further refined the analyses of potential rail corridors in Study 1.

Public comments submitted to DOE during hearings on the scope of this EIS resulted in the addition of a fifth potential rail corridor—Caliente/Chalk Mountain.

The analysis of impacts for the five Nevada rail transportation implementing alternatives assumed the mostly rail transportation scenario. Therefore, the analysis included the impacts of legal-weight truck transportation from six commercial sites that would not have the capability while operational to handle or load a large rail cask. About 1,079 legal-weight truck shipments over 24 years would enter Nevada and travel to the repository. These shipments would use the same transport routes and carry about the same amounts of spent nuclear fuel per shipment as those described for the mostly legal-weight truck scenario (Section 6.3.1).

The analysis evaluated impacts to land use and ownership; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.1 Impacts Common to Nevada Branch Rail Line Implementing Alternatives

The estimated life-cycle cost of constructing and operating a branch rail line in Nevada would range from $283 million to $880 million (2001 dollars), depending on the corridor and variation. This section discusses impacts for the analysis areas listed above that would be common to all five branch rail line implementing alternatives. DOE evaluated these impacts as described in Section 6.3. The construction of the branch rail line would last between 40 and 46 months, depending on the rail corridor. Shipping operations in the rail corridor would begin at a mainline siding where railcars carrying casks of spent nuclear fuel and high-level radioactive waste would switch from the mainline to the branch line for transport to the repository, and railcars carrying empty casks from the repository would switch to the mainline for transport back to the commercial and DOE sites. These shipments would continue for 24 years. Section 6.3.2.2 discusses impacts specific to each rail implementing alternative.

6.3.2.1.1 *Common Rail Land-Use and Ownership Impacts*

In identifying the land potentially affected by a rail corridor, the analysis assumed a corridor width of 400 meters (1,300 feet, or about 0.25 mile). The purpose of the 400-meter width was to provide sufficient space for final alignment to route the rail line around sensitive land features or engineering obstacles. Actual construction and operation in the corridor would mostly require less than about 60 meters (200 feet) of the 400-meter width. Thus, at most, about 15 percent of the land in the corridor would be disturbed by construction. The analysis also assumed that as much as 3.6 square kilometers (890 acres) of land outside of the main disturbed area within the corridor would be disturbed during the construction of a branch rail line for construction roads and camps and other construction-related activities.

Each rail corridor has possible variations providing different land ownerships and projected disturbances, as described in Appendix J, Section J.3.1.2. These possible variations would make little difference in land-use impacts, which could be more or less than those described below.

The analysis indicates no conflicts with commercial use and no identified conflicts with scientific studies for any of the proposed corridors. At present, the public land in each corridor, with the exception of portions of the Caliente-Chalk Mountain Corridor, is open to mining and recreational use, as discussed in Chapter 3, Section 3.2.2.1.1.

The construction and operation of a branch rail line in any of the rail corridors would directly and indirectly affect private property. The Valley Modified Corridor would have the smallest range of private land affected, from 7.3 to 0.2 square kilometer (45 acres). The Carlin Corridor would have the largest, from 7.3 to 15 square kilometers (1,800 to 3,700 acres). Most of the private property in the Carlin Corridor is in the vicinity of Beowawe and Crescent Valley. The ownership of each parcel of affected private land would require that DOE negotiate use arrangements with owners. The division of private property parcels could affect the current and future use of the property. Each corridor contains lands associated with the Nevada Test Site and managed by DOE. The amount of land in each corridor varies from 5 square kilometers (1,200 acres) for the Carlin and Caliente Corridors to 38 square kilometers (9,400 acres) for the Caliente-Chalk Mountain Corridor. With the exception of the Caliente-Chalk Mountain Corridor, the corridors cross Nevada Test Site lands only at entry points to the repository site close to the perimeter of the property and would be unlikely to result in a change of current land use. The Caliente-Chalk Mountain Corridor would enter the northeast portion of the Test Site and pass generally through the center of the site. Although this corridor would not result in a change of ownership, it would alter the current use of the land in the vicinity of the rail corridor.

Each rail corridor, with the exception of the Jean Corridor, would cross a portion of the Nellis Air Force Range (also known as the Nevada Test and Training Range) under the management of the U.S. Air Force. Lands along the corridors managed by the Air Force range from none for the Jean Corridor to 22 square kilometers (5,400 acres) for the Caliente-Chalk Mountain Corridor. The Caliente-Chalk Mountain Corridor would enter Nellis Air Force Range lands along the northern boundary and cross approximately 52 kilometers (32 miles) of land used for Department of Defense training operations.

The U.S. Air Force has identified national security issues in relation to a Caliente-Chalk Mountain Corridor, citing interference with Nellis Air Force Range testing and training activities (DIRS 104887-Henderson 1997, all). In response to Air Force concerns, DOE regards this route as a “nonpreferred alternative.”

As of July 2001, the Nevada Public Utility Commission’s website listed 20 electric power generating facilities scheduled for construction in Nevada by 2004. Five of the 20 plants have received permits to proceed. Two of these are located in Storey County and Pershing County. Three are in Clark County—one in North Las Vegas and two for the same company in an industrial park at Apex. None is anticipated to impact land use for the repository or the transportation routes. The remaining 15 sites are anticipated to begin construction through 2002. The rights-of-way associated with the new plants are likely to cross Bureau of Land Management land. Of the 20 plants proposed, 13 are scheduled for construction in Clark County. These are on private, public, and reservation lands. None of the 20 proposed power plants would be within 50 miles (80 kilometers) of the proposed repository at Yucca Mountain. In addition, none of the proposed plant locations would conflict with any of the proposed transportation route options. The transmission lines and natural gas utility rights-of-way for the proposed locations could cross potential transportation routes. Current documentation is not sufficient to determine the locations for the proposed transmission line and natural gas rights-of-way. Conflicts due to proposed power plant rights-of-way would predominantly be associated with the proposed rail corridors and would be similar to existing rights-of-way discussed later in this section.

Each corridor has areas the public uses and areas available for sale and transfer. Each corridor crosses some roads used to access recreation areas on State of Nevada and Federal lands that are outside the corridors. As a consequence, the proposed branch rail line could result in limited access to areas currently in use by the public. Similarly, because of the corridor interface with grazing lands and wildlife areas, a rail line could create a barrier to livestock movement. Impacts to wildlife are discussed later in this section. Each corridor crosses road, highway, or utility rights-of-way. The passage of a branch rail line through these areas could result in land-use conflicts that, in turn, could result in the transfer of lands in the rights-of-way to DOE or a renegotiation of rights-of-way.

Construction. DOE expects the potential impacts of construction to be greater than those during the operation of a rail corridor. If the repository was approved and a rail corridor was selected, the following impacts from the construction of a branch rail line could occur:

- Difficulty for cattle to access water if the corridor divided Bureau of Land Management grazing allotments. Disruption of ranch operations and livestock rotations. Livestock deaths along roads used during construction. Disruptions to use of access roads to grazing allotments which typically consist of two-track roads and crisscross many of the corridors.

- Effects to private property divided by a branch rail line if alternative access was not available or provided. Although DOE would mitigate construction activities through stringent construction practices, those practices could affect property use, especially if the property was inhabited.

- Effects to mining activities such as mine operations or exploration if access roads were temporarily blocked or altered. Divided mining claims, making development of a claim less profitable if access became a problem.

- Effects on access to recreational areas. Division of some Bureau of Land Management lands currently used for recreation, which could temporarily isolate sections of land from the general public. Less ease of access in areas where Federal and State recreation areas can be accessed by roads (including two-track roads) from Bureau lands. Alteration of the recreational experience for some users; for example, construction of a rail corridor close to Bureau lands set aside for primitive and semiprimitive recreational use would alter those experiences.

- Effects on rights-of-way. Construction through these areas would require an evaluation of the impact to the road or utility or use of the right-of-way. Alteration of the construction of current roads or utility lines. Alteration of above-ground utility lines to pass beneath the branch rail line through an underpass to enable continued access to the utilities for maintenance. Movement of overhead transmission towers and poles to accommodate the branch rail line. Use of bridges or underpasses across high-volume roads to preclude at-grade crossings. Use of fencing where increased public contact could occur.

DOE would consult with the Bureau of Land Management, U.S. Air Force, other affected agencies, and other DOE program operations on the Nevada Test Site to help ensure that the final alignment of a branch rail line avoided or mitigated potential land-use conflicts.

Operations. DOE expects the operation of a rail line to cause smaller impacts than would construction. If the repository was approved and a rail corridor was selected, the following impacts of the operation of a branch rail line could occur:

- Division of some grazing lands. The Bureau of Land Management has stated that dividing grazing lands would result in a small loss of animal-unit months in large allotments, but would probably not affect ranch operations as long as there was available access across the corridor. (An *animal-unit month* represents enough dry forage for one mature cow for one month.) The loss of animal-unit months could affect the permittee's operation. In addition, the Bureau indicated that, if a branch rail line divided an allotment into separate pastures, an opportunity to rotate pasture use and thereby enable new grazing management options could be beneficial to livestock and vegetation. The Bureau acknowledges that fencing could be required along corridors where there are grazing allotments and that livestock could be isolated from water. Under these circumstances, water would have to be hauled to livestock or supplied in some other manner. In relation to branch rail line operations, train and track inspection and maintenance activities would be confined to areas disturbed by construction activities, so no additional disturbances would occur.

- No additional impacts to land use as long as there was property accessibility.

- No effects on mining activities over the long term. Effects on mining exploration if access to leases was blocked or restricted, but current mining operations probably would remain accessible.

- Effects to access to recreational areas. Division of Bureau of Land Management lands currently used for recreation and for access to Federal and State lands, which could limit access to portions of those lands. Alteration of the recreational experience for some users; for example, operation of a rail corridor close to Bureau lands set aside for primitive and semiprimitive recreational use could alter those recreational experiences.

6.3.2.1.2 *Common Rail Air Quality Impacts*

Construction. The construction of a branch rail line would comply with all applicable air quality regulations and associated requirements in the construction permits. Construction activities would increase pollutant concentrations in the areas near the rail corridor or any of the variations described in subsequent sections. Fuel use by construction equipment would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter with diameters of 10 micrometers or less (PM_{10}) and 2.5 micrometers or less ($PM_{2.5}$). Construction activities would also emit PM_{10} in the form of fugitive dust from excavation and truck traffic. The emissions would be temporary and would cover a very large area as construction moved along the length of the corridor.

No air quality impacts would be unique to the branch rail line implementing alternatives with the exception of the Valley Modified Corridor, as described in Section 6.3.2.2.5.

Operations. Fuel use by diesel train engines would emit carbon monoxide, nitrogen dioxide, PM_{10}, and $PM_{2.5}$. Based on the Federal standards for locomotives (40 CFR 92.005), there are no emission standards for sulfur dioxide.

DOE conducted a conformity review using the guidance in DIRS 155566-DOE (2000, all) for the transportation activities of the Nevada rail implementing alternatives. The Las Vegas air basin is in nonattainment status for carbon monoxide, which is largely a result of vehicle emissions (DIRS 156706-Clark County 2000, Appendix A, Table 1-3). The review determined that during the construction phase carbon monoxide emissions from the transportation of employees, materials, and supplies and from engine exhaust of construction vehicles working on the Valley Modified route could exceed the Clean Air Act General Conformity threshold level (about 110 to 160 percent of the threshold). These emission estimates represent about 0.1 to 0.2 percent of the 2000 daily carbon monoxide levels in the Las Vegas air basin. More detailed planning probably would result in emissions below the threshold. Emissions during the construction of all other routes and during repository operations would not exceed the carbon monoxide General Conformity threshold level in the nonattainment area.

The Las Vegas air basin is also in nonattainment status for PM_{10}, which is largely a result of dust from construction activities (DIRS 155557-Clark County 2001, Tables 3-8 and 5-3). The conformity review determined that PM_{10} emissions from the fugitive dust generated by Valley Modified route construction could exceed the General Conformity threshold level for PM_{10} (see Section 6.3.2.2.5.2). Additional dust control measures and construction planning in the nonattainment area could reduce the emissions to levels below the threshold. Emissions during the construction of all other routes and during the operation of any of those routes would not exceed the PM_{10} General Conformity threshold levels in the nonattainment area.

No air quality impacts would be unique to the branch rail line implementing alternatives with the exception of the Valley Modified Corridor, as described in Section 6.3.2.2.5.

6.3.2.1.3 *Common Rail Hydrology Impacts*

This section describes impacts to surface water and groundwater.

Surface Water

Construction. Construction-related impacts could involve the possible release and spread of contaminants by precipitation or intermittent runoff events or, for corridors near surface water, possible release to the surface water, the alteration of natural drainage patterns or runoff rates that could affect downgradient resources, and the need for dredging or filling of perennial or ephemeral streams.

Construction-related materials that could cause contamination would consist of petroleum products (fuels and lubricants) and coolants (antifreeze) necessary to support equipment operations. In addition, remote work camps would include some bulk storage of these materials, and supply trucks would routinely bring new materials and remove used materials (lubricants and coolants) from the construction sites. These activities would present some potential for spills and releases. Compliance with regulatory requirements on reporting and remediating spills and properly disposing of or recycling used materials would result in a low probability of spills. If a spill occurred, the potential for contamination to enter flowing surface water would present the greatest risk of a large migration of a contaminant before remediation took place. If there was no routinely flowing surface water (most areas along the corridors), released material would not travel far or affect critical resources before remediation occurred. During construction activities, water spraying would control dust and achieve soil compaction criteria, but water would not be used in quantities large enough to support surface-water flow and possible contaminant transport for any distance.

During construction, a contractor would move large amounts of soil and rock to develop the track platform (subgrade) and the access road. These construction activities could block storm drainage channels temporarily. However, the contractor would use standard engineering design and best management practices to place culverts, as appropriate, to move runoff water from one side of the track or road to the other. These culverts or other means of runoff control would be put in place early in the construction effort, because standing water in the work area would generally hinder progress.

Depending on site-specific conditions, construction could include regrading such that a number of minor drainage channels would collect in a single culvert, resulting in water flowing from a single location on the downstream side rather than across a broader area. This would cause some localized changes in drainage patterns but probably would occur only in areas where natural drainage channels are small.

All of the rail corridors would cross 100-year flood zones as identified on Flood Insurance Rate Maps published by the Federal Emergency Management Agency. None of the corridors has complete coverage (the percentage of the rail corridor included on the flood zone maps) on these maps due to large unstudied areas such as the Nellis Air Force Range and the Nevada Test Site, and areas with very limited coverage such as Lincoln County. For example, coverage by these flood maps ranges from about 10 percent for the Caliente-Chalk Mountain Corridor to about 90 percent for the Jean Corridor. However, the available information does provide an idea of corridor-specific flood zones, as summarized in the individual corridor discussions in Sections 6.3.2.2.1 to 6.3.2.2.5. In general, construction-related impacts associated with these flood zones would be very similar to those that could occur in any other identified drainage areas (that is, the alteration of natural drainage patterns and possible changes in erosion and sedimentation rates or locations). Construction in washes or other flood-prone areas probably would reduce the area through which floodwaters naturally flow. This could result in water building up, or ponding, on the upstream side of crossings during flood events, and then slowly draining through the culverts or bridges. Sedimentation would be likely on the upstream side of structures in such events and, accordingly, water going through the structure could be more prone to cause erosion once on the downstream side. Maintenance of a branch rail line would require periodic inspections of flood-prone areas (particularly after flood events) to verify the condition of the track and drainage structures. When necessary, sediment accumulating in these areas would be removed and disposed of appropriately. Similarly, eroded areas encroaching on the track bed would be repaired.

These alterations to natural drainage, sedimentation, and erosion would be unlikely to increase future flood damage, increase the impact of floods on human health and safety, or cause significant harm to the natural and beneficial values of the floodplains. Flood zone impacts would be minor primarily because of the relatively limited size of the disturbance that would be necessary to construct a branch rail line, and because the rail line design would accommodate a 100-year flood. In addition, the candidate rail corridors are in a region where flash flooding events are the primary concern. Though such flooding can be very violent and hazardous, it is generally focused in its extent and duration, limiting the potential for extensive impacts associated with the rail line. If DOE selected a rail corridor, it would initiate additional engineering and environmental studies and would perform additional National Environmental Policy Act reviews as a basis for final alignment selection and construction. DOE would then prepare a more detailed floodplain/wetlands assessment of the selected alternative.

Operations. The use of a completed branch rail line would have little impact on surface waters beyond the permanent drainage alterations from construction. The road and rail beds probably would have runoff rates different from those of the natural terrain but, given the relatively small size of the potentially affected areas in a single drainage system, there would be little impact on overall runoff quantities.

There would be no surface-water impacts unique to any of the branch rail line implementing alternatives with the exception of their relative proximity to surface-water resources.

Appendix L contains a floodplain/wetlands assessment that examines the effects of branch rail line construction, operation, and maintenance on the following floodplains in the vicinity of Yucca Mountain: Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash (see Section L.4.1). There are no delineated wetlands at Yucca Mountain. This section on common impacts and the following section on corridor-specific impacts address, in general terms, the flood zones along the rail corridors outside the immediate vicinity of Yucca Mountain. Appendix L, Section L.3.2, contains additional information on these portions of the corridors.

Groundwater

Construction. Potential groundwater impacts from rail line construction could include changes to infiltration rates, new sources of contamination that could migrate to groundwater, and depletion of groundwater resources resulting from increased demand. However, the potential for impacts would be spread over a large geographic area, so the probability would be low for a resource in a single area to receive adverse impacts. The above discussion of impacts to surface water identifies potential contaminants that branch rail line construction could release. These contaminants would be the same for groundwater.

Construction activities would disturb and loosen the ground, which could produce greater infiltration rates. However, this situation would be short-lived as the access road and railbed materials became compacted and less porous. In either case, localized changes in infiltration probably would cause no noticeable change in the amount of recharge in the area.

The analysis assumed that a number of wells would be required to support construction and that they would be installed along the rail corridor. It also assumed a 1-year period for construction activities in the vicinity of each well. Water withdrawal from these wells would not contribute to the depletion of a particular groundwater basin for two reasons: (1) the demand would be relatively short-term because it would stop when construction was complete, and (2) annual demands would be limited to a fraction of the perennial yields of the aquifers that would supply the water (see Chapter 3, Section 3.1.4). In addition, the Nevada State Engineer would approve water production from any well installed to support rail corridor construction. To grant approval, the State Engineer would have to determine that the short-term demand would not cause adverse impacts for other uses and users of the groundwater resource.

For the case in which water was obtained from a source other than a newly installed well and brought to the construction site by truck, water would be obtained from appropriated sources. That is, the water would be from allocations that the Nevada State Engineer had previously determined did not adversely affect groundwater resources.

Impacts on groundwater would differ among the implementing alternatives. These impacts, which Section 6.3.2.2 describes for the implementing alternatives, would include the projected water needs to support the construction of each candidate rail corridor and the estimated number of wells DOE would install along each corridor to meet that need.

Operations. The use of a completed railway corridor would have little impact on groundwater resources. There would be no continued need for water along the corridor, and possible changes to recharge, if any, would be the same as those at the completion of construction.

6.3.2.1.4 *Common Rail Biological Resources and Soils Impacts*

Construction. Construction activities would generally disturb no more than about 15 percent of the land inside a 400-meter (0.25-mile)-wide corridor. Vegetation would be cleared in an area generally less than 60 meters (200 feet) wide in the corridor to enable the construction of a branch rail line and a parallel access road. Vegetation would also be cleared from borrow areas and covered in disposal areas for excavated materials. Land for construction camps and in small areas where wells would be drilled would also be cleared of vegetation. Clearing vegetation and disturbing the soil would create habitat for colonization by exotic plant species present along a corridor. This could result in an increase in abundance of exotic species along the corridor, which could result in suppression of native species and increased fuel loads for fire. Reclamation of disturbed areas would enhance the recovery of native vegetation and reduce colonization by exotic species.

Impacts to biological resources from the construction of a branch rail line would occur due to a loss of habitat for some terrestrial species. Individuals of some species would be displaced or killed by construction activities. After the selection of a rail corridor, DOE would perform preconstruction surveys of potentially disturbed areas to identify and locate special status species that would need to be protected during construction.

Construction could affect the following biological resources:

- *Game and Game Habitat and Wild Horses and Burros.* Each candidate rail corridor or its variations would cross or be near [within 5 kilometers (3 miles)] several areas the Bureau of Land Management and the Nevada Division of Wildlife have designated as game habitat or wild horse and burro management areas (DIRS 104593-CRWMS M&O 1999, pp. 3-23 to 3-32). Construction activities in these areas would result in a loss of some habitat. Each rail corridor has the potential to disrupt movement patterns of game animals and wild horses and burros. The design of fences, if built along a rail corridor, would accommodate the movement of these animals. Large animals including game species (elk, bighorn sheep, mule deer, etc.), wild horses, and burros probably would avoid contact with humans at construction locations and would temporarily move to other areas during construction. Larger game animals occupy large home ranges and could easily traverse the distance between their designated habitat and a proposed corridor. Construction activities probably would disturb individuals or groups of animals and they would avoid the areas where construction was occurring. Fencing of the rail line could disrupt movements of horses, burros, and game animals, but the branch rail line would be designed to accommodate animal movement, to the extent possible, with such features as underpasses to enable large animals to cross from one side to the other. In the absence of fencing, movements of large animals would not be disrupted by the long-term presence of a rail line, but the possibility of trains colliding with game animals would be greater.

- *Special Status Species.* The construction of a branch rail line in any of the five rail corridors or their variations would involve the loss of varying amounts [3 to 11 square kilometers (740 to 2,700 acres)] of desert tortoise habitat. None of the corridors cross areas designated by the Fish and Wildlife Service as critical desert tortoise habitat (50 CFR 17.95). The abundance of tortoises varies from very low to medium along the proposed corridors (DIRS 101840-Karl 1980, pp. 75 to 87; DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411), but some desert tortoise deaths could occur during land-clearing operations. Numerous special status species occur along each of the proposed branch rail lines. Construction of a branch rail line could lead to habitat loss and fragmentation for the special status species, as well as to mortality of individuals.

- *Wetlands and Riparian Areas.* Each corridor could affect wetlands, springs, and riparian areas (DIRS 104593-CRWMS M&O 1999, pp. 3-23 to 3-32). These areas are generally important for biological resources and typically have high biodiversity. Potential impacts to these areas include destruction, alteration, or fragmentation of habitat; increased siltation in streams during construction; changes in stream flow; and loss of biodiversity.

- *Prime Farmland.* DOE identified no prime farmland for any corridor or route.

Section 6.3.2.2 describes the impacts to biological resources that would be unique for each corridor.

All of the candidate rail corridors and their variations would cross perennial or ephemeral streams that could be classified as jurisdictional waters of the United States. Section 404 of the Clean Water Act regulates discharges of dredged or fill material into such waters. After the selection of a rail corridor, DOE would identify any jurisdictional waters of the United States that the construction of a rail line would affect; develop a plan to avoid when possible, and otherwise minimize, impacts to those waters;

and, as applicable, obtain an individual or regional permit from the U.S. Army Corps of Engineers for the discharge of dredged or fill material. By implementing the plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be small.

The general design criteria for a branch rail line would include a requirement that a 100-year flood would not inundate the rails at channels fed by sizable drainage areas. During the operation and monitoring phase of the repository, conditions more intense than those that would generate a 100-year storm could occur in the area. Such conditions, depending on their intensity, could wash out access roads and possibly even the rail line. Although DOE would have to repair these structures, there is no reason to believe that such an occurrence would unduly affect area resources. If necessary, a permit would be obtained from the U.S. Army Corps of Engineers for discharge of dredge and fill material to repair the rail line. There would be no contamination that floodwaters could spread and, with the exception of areas of steep terrain, debris would not travel far. The operation of a branch rail line would stop during conditions that could lead to the flooding of track areas and would not resume until DOE had made necessary repairs.

Soil impacts from branch rail line construction would be primarily the direct impacts of land disturbance in the selected corridor. The amount of land disturbance, both inside and outside the corridor, would vary by corridor. The disturbed areas probably would be subject to an increase in erosion potential during construction. DOE would use dust suppression measures to reduce this potential. As construction proceeded, the railbed would be covered with ballast rock, which would virtually halt erosion from that area, and the access roads would be compacted, and gravelled, which would reduce erosion. As construction ended, disturbed areas (other than the railbed and access roads) would slowly recover. Other permanent erosion control systems would be installed as appropriate. Introduction of contaminants into the soil is also a potential concern. Proper control of hazardous materials during construction and prompt response to spills or releases would, however, reduce this concern. Impacts to soils would be limited to these areas disturbed and would be transitory and small.

Operations. Impacts to biological resources from shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository along any of the five rail corridors, including their variations, would include periodic disturbances of wildlife from trains going by and from personnel servicing the corridor. Trains probably would kill individuals of some species.

Rail operations would not lead to additional habitat losses, although maintenance activities would prevent habitat recovery in the narrow band occupied by the branch rail line and access road. In addition, there could be loss of habitat due to inadvertent fires along the right-of-way from rolling equipment operations and maintenance activities. Although trains probably would kill individuals of some species, losses would be unlikely to affect regional populations of any species because all species are widespread geographically and trains would only use the corridor once or twice per day. Fewer individuals of large species would be likely to be killed during operations if the corridor was fenced, but fencing could restrict animal movement and disrupt migration patterns. Furthermore, fences would require continual surveillance to prevent individual animals or herds from becoming trapped. Nevertheless, the demographics of small herds could be adversely affected if individuals important to the viability of the herd were struck by a train. Fencing of the branch rail line and other features, such as tunnels (Jean Corridor), could lead to losses of individual animals or groups of animals. Individual animals could become caught inside fenced sections of the railroad and fail to find escape from oncoming trains. Game animals, horses, or burros could seek shelter in a tunnel and fail to escape if a train passed through.

Passing trains could disrupt wildlife, including game animals, horses, and burros, but such effects would be transitory. Noise from a train probably would disturb animals close to the track throughout operations, but this disturbance would diminish with distance from the track and over time as animals acclimated to daily disturbances from passing trains. The frequency of trains using the corridor (estimated to be 10 per week, 5 in each direction) indicates that disturbance of animals near the rail line would probably be minimal. Noise from the trains could cause animals to move away from the tracks and, possibly, cause changes in migratory patterns.

Trains, and the presence of the branch rail line, could lead to the death of individual desert tortoises. DOE would consult with the Fish and Wildlife Service under Section 7 of the Endangered Species Act on means of mitigating the potential for losses, and would implement all terms and conditions required by the Fish and Wildlife Service.

No additional habitat loss would occur during operations, although the loss of habitat could become permanent if a long-term use for the rail line became viable after completion of the repository project and operations continued.

Impacts to soils from operation of the branch rail line would be small because train movement would not disturb soils and maintenance of the railbed and rails would involve minimal disturbance beyond that which had occurred during the construction of the rail line.

6.3.2.1.5 *Common Rail Cultural Resources Impacts*

Construction. Chapter 3, Section 3.2.2.1.5 lists the archaeological information currently available in each corridor that branch rail line construction could affect, including tables that list linear historic properties (for example, the Pony Express Trail) and sites listed on State of Nevada and national historic registers, respectively. DIRS 155826-Nickens and Hartwell (2001, all) contains more information about known and potential cultural resources along the candidate corridors and their variations. Direct impacts to these cultural resources (such as disturbing the sites or crushing artifacts) could occur from a variety of construction-related activities, including building the rail line and the right-of-way. In addition, rail line construction activities would include borrow areas, areas for the disposal of excavated material, construction camps, and access roads that would be outside the defined right-of-way. Because archaeological sites sometimes include buried components, ground-disturbing actions could uncover previously unidentified cultural materials. If cultural resources were encountered, a qualified archaeologist would participate in directing activities to ensure that the resources would be properly protected or the impact mitigated. DOE would use procedures to avoid or reduce direct impacts to cultural resources in construction areas where surface-disturbing activities would occur (see Chapter 9).

Indirect impacts, such as non-project-related disturbances of archaeological sites by purposeful or accidental actions of project employees, could occur from construction activities as a result of increased access and increased numbers of workers near cultural resource sites. These factors would increase the probability for either intentional or inadvertent indirect impacts to cultural resources. Section 6.3.2.2 discusses potential impacts specific to each corridor.

Systematic studies would be completed for a selected corridor to identify sites, resources, or areas that might hold traditional value for Native American peoples or communities. Two of the corridors (Caliente and Carlin) could affect as-yet unidentified resources because they could pass through the Timbisha Shoshone Trust Lands parcel near Scottys Junction. If sites or resources important to Native Americans were discovered in the future, either in or near an identified right-of-way, adverse effects could occur through direct means, such as construction activities, or indirectly through visual or auditory (sound and vibration) impacts.

In the viewpoint of Native Americans, the construction and operation of a branch rail line would constitute an intrusion on the holy lands of the Southern Paiute and Western Shoshone. In addition, some corridors pass through or near several significant places (see Chapter 3, Section 3.2.2.1.5). The American Indian Writers Subgroup has commented that the overall significance of these places and potential impacts from operation of a rail line on them cannot be fully understood until DOE has identified the rail alignment and completed ethnographic field studies and consultations (DIRS 102043-AIWS 1998, p. 4-6). If DOE selected a rail corridor, it would initiate additional engineering and environmental studies (including cultural resource surveys), conduct consultations with Federal agencies, the State of Nevada, and tribal governments, and perform additional National Environmental Policy Act reviews as a basis for final alignment selection and construction. DOE would address the mitigation of potential impacts to archaeological and historic sites during the identification, evaluation, and treatment planning phases of the cultural resource surveys.

Operations. No additional direct or indirect impacts would be likely at archaeological and historic sites from the operation of a branch rail line. However, if Native Americans identified specific concerns during the preconstruction consultations described above, DOE would address them at that time.

6.3.2.1.6 *Common Rail Occupational and Public Health and Safety Impacts*

Incident-Free Transportation. Incident-free impacts of rail transportation in Nevada would be unique for each of the five Nevada rail transportation implementing alternatives; these are discussed for each implementing alternative in Section 6.3.2.2. Incident-free impacts to hypothetical maximally exposed individuals would be similar among the Nevada rail transportation implementing alternatives. Table 6-21 lists the impacts to hypothetical maximally exposed individuals in Nevada who would be exposed to all rail shipments along a branch rail line. Appendix J, Section J.1.3.2.2 describes assumptions for estimating doses to maximally exposed individuals along routes in Nevada.

Table 6-21. Estimated doses and radiological impacts to maximally exposed individuals for Nevada rail implementing alternatives.[a,b]

Individual	Dose (rem)	Probability of latent cancer fatality
Involved workers		
Inspector	34	0.012
Railyard crew member	4.2	0.002
Public		
Nevada resident along route (rail)[c]	0.002	0.0000008
Person in traffic jam (legal-weight truck)[d]	0.02	0.000008
Person at service station (legal-weight truck)[e]	0.08	0.00004
Resident near rail stop	0.29	0.0001

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operation.
c. This represents a Nevada resident approximately 30 meters (98 feet) from the branch rail line. See Appendix J, Section J.1.3.2.2.
d. Person in a traffic jam is assumed to be exposed one time only.
e. Assumes the person works at the service station for all 24 years of operations. Mitigation would be required to reduce doses to members of the public to below 100 millirem per year.

Accidents. Accident risks and maximum reasonably foreseeable accidents for rail shipments of spent nuclear fuel and high-level radioactive waste would be common to the Nevada rail transportation implementing alternatives. This section, therefore, discusses these risks.

Table 6-22 lists accident risks for transporting spent nuclear fuel and high-level radioactive waste in Nevada for the five Nevada rail transportation implementing alternatives. The data show that the risks, which are listed for 24 years of operations, would be low for each alternative. These risks include risks associated with transporting 1,079 legal-weight truck shipments made from the commercial sites that could not load rail casks while operational. Small variations in the risk values, principally evident for the Jean branch rail line, are a result of risks that would be associated with transporting rail casks arriving from the east on the Union Pacific Railroad's mainline through the Las Vegas metropolitan area. The values that would apply for a Valley Modified or Caliente-Chalk Mountain branch line would be lower

Table 6-22. Estimated health impacts[a] to the public from potential accident scenarios for Nevada rail implementing alternatives.

Risk	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Radiological accident risk[b]					
Dose risk (person-rem)	0.0017	0.0026	0.0017	0.0071	0.0021
LCFs[c]	0.0000009	0.0000013	0.0000009	0.000004	0.000001
Traffic fatalities	0.07	0.09	0.05	0.06	0.05

a. Data are reported for 24 years of operations.
b. In this table, radiological accident dose risk is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. This sum is converted to latent cancer fatalities using the conversion factor of 0.0005 latent cancer fatality per person-rem.
c. LCF = latent cancer fatality.

because of a shorter corridor (Valley Modified), or a more remote and mid-length corridor (Caliente-Chalk Mountain).

Consequences of Maximum Reasonably Foreseeable Accidents. The national transportation analysis evaluated impacts of maximum reasonably foreseeable accidents (see Section 6.2.4.2).

6.3.2.1.7 *Common Rail Socioeconomics Impacts*

The common social and economic activities and changes associated with the construction of a branch rail line include:

- A period of brief, intense elevation in project-related employment followed by an abrupt decrease in associated employment opportunities as construction workers move to other projects.
- Transition of workers associated with construction of the branch rail line to other construction work in Nevada (if these workers did not move into positions associated with rail line operations).
- Population increases and then subsequent net declines as related employment requirements decline.
- A very slightly slower rate of growth in the level of employment as the economy moved from construction of a rail line to operations.
- A rise in the economic measures of real disposable income, Gross Regional Product, and State and local government expenditures during construction. Gross Regional Product, which is extremely sensitive to employment fluctuations, would be affected. Real disposable income, which consists of all forms of income including transfer payments (primarily unemployment compensation), is less responsive to changes in employment.

DOE performed detailed analyses for the corridors of the five branch rail line implementing alternatives. The results of these analyses, driven by the length of the corridor, are representative of the potential variations (options and alternates) of each corridor as listed in Appendix J, Section J.3.1.2. The lengths of the variations for each corridor are similar to the original corridor, as listed in Section 6.3.2.2.

Section 6.3.2.2 describes socioeconomic impacts for each particular implementing alternative.

6.3.2.1.8 *Common Rail Noise and Vibration Impacts*

Construction. For the most part, the rail corridors would pass through areas that are remote from human habitation. Thus, the potential for noise impacts from the construction of a branch rail line would be limited. Nonetheless, some people could be affected, including persons living near the corridor, using nearby recreational areas, seeking quiet and solitude at nearby locations, or living in nearby small rural communities. Noise from railroad construction could affect wild animals that inhabit the areas through which the corridors pass. However, construction noise would be transient and its sources would be gone when construction was complete.

Estimated noise levels for railroad construction would range from 62 to 74 A-weighted decibels (dBA) within 150 meters (500 feet) of the noise source and from 54 to 67 dBA at 600 meters (2,000 feet) (DIRS 104892-ICC 1992, p. 4-97). At distances up to 6 kilometers (3.7 miles), sound could exceed levels required for solitude (20 dBA). Trips to borrow and spoil areas would be another source of noise. Rail line construction would occur primarily during daylight hours, so nighttime noise would not be an issue unless there was a need to use accelerated construction to meet schedule constraints. There is a possibility that the construction of some structures associated with the rail line would occur during hours not in the normal workday, but the frequency and associated noise levels would be unlikely to be great. Because construction would progress along a corridor, construction noise would be transient in nearby communities. Noise levels could approach generally accepted limits for some residential and commercial areas, but this would be for a brief time. Because there are no permanent residences, construction noise would not be an issue for activities inside the boundaries of the Nellis Air Force Range, the Nevada Test Site, or the land withdrawal area that DOE analyzed for the proposed repository. Occupational Health and Safety Administration regulations (29 CFR) establish hearing protection standards for workers. DOE would meet those standards for workers involved in building a branch rail line.

Ground vibration from the construction of engineered structures, such as bridge foundations, could be discernible in some areas. The areas that would be affected would be determined by engineering surveys and detailed alignment analyses conducted after the selection of a corridor.

Operations. About five rail round trips (10 one-way trips) of spent nuclear fuel, high-level radioactive waste, or other material would occur weekly for 24 years on the branch rail line during normal operations. Noise from these trains could affect the same group of individuals and animals as construction of the rail line. To estimate noise impacts, the analysis assumed that trains would travel as fast as 80 kilometers (50 miles) an hour. The equivalent-continuous (average) sound level at 2,000 meters (6,600 feet) from a train consisting of two locomotives and 10 cars traveling at 80 kilometers an hour would be 51 dBA (DIRS 148155-Hanson, Saurenman, and Towers 1998, pp. 1 to 8), which is near the nighttime standard for residential areas (50 dBA). The estimated noise level at 200 meters (660 feet) would be 62 dBA (DIRS 148155-Hanson, Saurenman, and Towers 1998, pp. 1 to 8). This is slightly higher than the daytime standard for residential communities. In isolated regions, few people would be affected. In addition, trains traveling through or near communities would normally operate at reduced speed, so their noise levels would be lower. The combination of sparse population in the vicinity of the rail corridors, remoteness of a branch rail line from populated areas, substantial diminishing of the level of train noise with distance, and infrequent passage of trains indicates that the potential for noise impacts would be low for any of the corridors. In addition, in areas where a branch rail line or a variation could pass near a community, DOE would limit operating speeds to the extent necessary to ensure safety and noise levels below those listed in accepted noise standards.

DOE is not aware of traditional cultural properties or other areas along the rail corridors or variations where noise from trains or construction of a branch rail line could interfere with conditions necessary for meditation by, or religious ceremonies of, Native Americans. Similarly, there are no known ruins or other culturally sensitive structures that ground vibration could affect.

Ground vibration from trains using a branch rail line to Yucca Mountain would have the potential to cause impacts (see Section 6.3). Sections 6.3.2.2.1 to 6.3.2.2.5 discuss specific issues related to vibration for each corridor.

DIRS 155939-Nelson (2000, Appendix F, Table 1, p. 4) discussed vibration criteria for protection of historic buildings and presented data on vibration (peak particle velocity) for unit coal trains. Unit coal trains can consist of many loaded coal cars (usually more than 100) and multiple locomotives. The data (DIRS 155939-Nelson 2000, Appendix F) show that at distances of 100 meters (330 feet) from the track and for track not specially selected to reduce vibration, vibration from trains traveling at 56 kilometers (35 miles) per hour would be below the criterion for preservation of historic structures. Vibration from trains traveling on track that does not have rolling-mill undulation falls below the criterion at distances as close as 10 meters (33 feet) and speeds as high as 80 kilometers (50 miles) per hour. For shorter trains, such as those that would transport railcars with spent nuclear fuel and high-level radioactive waste to Yucca Mountain, attenuation of vibration with distance would be greater than that reported (DIRS 155939-Nelson 2000, p. 23).

6.3.2.1.9 *Common Rail Aesthetics Impacts*

Construction. The greatest impact on visual resources from the construction of a branch rail line would be the presence of workers, camps, vehicles, large earth-moving equipment, laydown yards, borrow areas, and dust generation. These activities, however, would have a limited duration (about 40 to 46 months depending on the corridor). The potential rail corridors and variations have all been affected to some extent by human activity, as described in Chapter 3, Section 3.2.2.1.1. Construction would progress along the selected corridor from its starting point to the proposed repository. Only a small portion of the overall construction time would be spent in one place; the exception to this would be places where major structures, such as bridges, would be built. In general, an individual construction camp would be active only for part of the construction period; after the completion of construction in an area, the camp would close.

Dust generation would be controlled by implementing best management practices such as misting or spraying disturbed areas. Construction activities would not exceed the criteria in the Bureau of Land Management Visual Resource Management guidelines (DIRS 101505-BLM 1986, all) with the exception of the Wilson Pass Option of the Jean Corridor. If the rail line crossed Class II lands, more stringent management and reclamation requirements would be necessary to retain as much as possible of the existing character of the landscape. The short duration of branch rail line construction activities, combined with the use of best management practices, would help mitigate the impacts of activities that could exceed the management requirements for Class II lands. Visual impacts to scenic quality Class C lands on the Nevada Test Site would not occur because of the remoteness and inaccessibility of the location. Impacts to the viewshed during construction of a branch rail line would include loss of vegetation in the areas surrounding the rail line. This loss could result in a long-term loss of viewshed along the corridor.

Operations. During proposed repository operations, visual impacts would be due to the existence of the branch rail line, access road, and borrow pits in the landscape and the passage of trains to and from the repository. The passage of 10 trains a week (5 coming and 5 returning) would have a small impact, temporarily attracting the attention of the casual observer. In limited access recreational areas classified as primitive or semiprimitive, the passage of these trains would have a greater impact. In addition, the noise generated by the trains would attract attention to them, temporarily increasing their impact on the scenic quality of the landscape. There would be no aesthetic impacts unique to any of the rail implementing alternatives.

6.3.2.1.10 *Common Rail Utilities, Energy, and Materials Impacts*

Construction. Because all five corridors would pass through sparsely populated areas with little access to support services, portable generators would provide electricity to support construction activities. The total fossil-fuel consumption in Nevada was about 3.8 billion liters (1 billion gallons) in 1996 (DIRS 148094-BTS 1997, Table MF-21). Fuel consumption estimates for construction of a branch rail line indicate low impacts compared to the statewide consumption of petroleum fuel.

Steel for rails and concrete, principally for rail ties, bridges, and drainage structures, and rock for ballast would be the primary materials consumed in the construction of a branch rail line. DOE would buy precast concrete railbed ties, culverts, bridge beams, and overpass components from a number of suppliers. Actual onsite pouring of concrete [less than 120,000 metric tons (132,000 tons)] would account for less than 30 percent of the total mass of concrete, which would be less than 0.5 percent of the concrete use in Nevada in 1998 (DIRS 104926-Bauhaus 1998, all). Because DOE would buy precast concrete components from suppliers and because onsite concrete construction would involve a small amount of material for some abutments, the localized impact of concrete use in rail corridor construction would not be great for any of the corridors.

Because sources for rails and railroad ties are well established in the southwest and nationally, none of the quantities of materials required for constructing a rail line in Nevada would create demand or supply impacts in southern Nevada (DIRS 105033-Zocher 1998, all).

Impacts on utilities, energy, and materials differ among the implementing alternatives, as described in Section 6.3.2.2.

Operations. Impacts to utilities, energy, and materials from the operation of a branch rail line in Nevada would be small. Use of fossil fuel for train operations would be small. Chapter 10 discusses fossil fuel used for rail operations. No impacts would be unique to any of the branch rail line implementing alternatives.

6.3.2.1.11 *Common Rail Waste Management Impacts*

Construction. The construction of a branch rail line would require materials such as rail ties and steel; rock ballast; concrete; oils, lubricants, and coolants for heavy machinery; and compressed gasses (hazardous materials) for welding. DOE could order construction materials in correct sizes and number, resulting in very small amounts of waste (DIRS 152540-Hoganson 2000, all). In addition, much of the residual material from rail line construction would be saved for reuse or recycled. Construction of the branch rail line, service road, and access roads would require land clearing. Excavated soil would be used for fill as much as possible. Vegetation would be disposed of in accordance with State of Nevada requirements. Construction in any of the five corridors would result in small amounts of waste that would require disposal. Wastes would consist of construction debris such as banding material that bound ties and rails (DIRS 152540-Hoganson 2000, all) that DOE would dispose of in permitted landfills. Hazardous waste such as lubricants and solvents, if any, would be shipped to a permitted hazardous waste treatment and disposal facility.

Sanitary solid waste and sanitary sewage from flush toilets and showers would be generated in construction camps. The estimated peak annual generation would be 940 metric tons (1,000 tons) of sanitary solid waste and 37 million liters (10 million gallons) of sanitary sewage. The solid waste would be disposed of in a permitted landfill. Nevada has 24 operating municipal solid waste landfills (DIRS 155564-NDEP 2001, p. 1) with a combined capacity to accept 11,000 metric tons (12,000 tons) of waste per day (DIRS 155563-NDEP 2001, landfill inventory). In 2000, approximately 3.5 million metric tons (3.9 million tons) of sanitary solid waste were disposed of in Nevada (DIRS 155565-NDEP 2001, Section 2.1), so the construction camp waste would add approximately 0.03 percent. The sanitary sewage could be treated in an onsite treatment facility for which the contractor had obtained the necessary permits. In addition, a commercial vendor would provide portable restroom facilities where needed and manage the sanitary sewage.

All waste would be handled in accordance with applicable environmental, occupational safety, and public health and safety requirements to minimize the possibility of adverse impacts from construction to plants, animals, soils, water resources, and air quality inside or outside the region of influence.

Operations. The use of a branch rail line in any of the five corridors would result in wastes from the maintenance of rolling and stationary railroad equipment and track. These wastes would include lubricants from equipment and machinery; solvents, paint, and other hazardous material; sanitary waste; and industrial wastes typical for operations of a small branch rail line. Operational wastes would include those generated during equipment maintenance. Maintenance of each locomotive would generate about 420 liters (110 gallons) of waste oil (DIRS 155559-Best 2001, all) that would be reclaimed rather than disposed. Worn or damaged parts and components would be repaired or remanufactured and returned to use. Routine maintenance of newer model rail cars would consist primarily of inspection and replacement of worn or damaged components. However, these cars are designed to last many years. In addition, sealed components would minimize the need for lubrication (DIRS 155558-Hoganson 2001, all). Routine maintenance and repair of rolling equipment would be performed at maintenance and repair yards operated by an independent contractor. Wastes from the maintenance of fixed rail line equipment such as signals and rail crossings would be minimal (DIRS 155560-Hoganson 2001, all). Crossties, ballast, rails, and bridges would be unlikely to require replacement before 2033 (DIRS 152540-Hoganson 2000, all). The management and disposition of operational wastes would comply with applicable environmental, occupational safety, and public health and safety regulations. Wastes would be handled such that adverse impacts from rail corridor operation waste to plants, animals, soils, air quality, and water resources along the right-of-way would be minimized.

There would be no waste management impacts unique to any of the branch rail line implementing alternatives.

6.3.2.2 Impacts Specific to Individual Rail Corridor Implementing Alternatives

6.3.2.2.1 *Caliente Corridor Implementing Alternative*

The Caliente Corridor would originate at an existing siding to the Union Pacific mainline railroad at Eccles siding near Caliente, Nevada (Figure 6-15). The corridor travels west, traversing the Chief, North Pahroc, Golden Gate, and Kawich Mountain Ranges. The Caliente and Carlin corridors converge near the northwest boundary of the Nellis Air Force Range. Past this point, the corridors are identical. The Caliente Corridor is 513 kilometers (319 miles) long from the Union Pacific line connection to the Yucca Mountain site. Variations of the route range from 512 to 553 kilometers (318 to 344 miles). Figure 6-15 shows this corridor, along with possible variations identified by engineering studies (DIRS 131242-CRWMS M&O 1997, all). The corridor variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-15. With the exception of the differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the same among the possible variations.

Construction of a branch rail line in the Caliente corridor would require approximately 46 months. Construction would take place simultaneously at multiple locations along the corridor. An estimated six construction camps at roughly equal distances along the corridor would provide temporary living accommodations for construction workers and construction support facilities. A train would take about

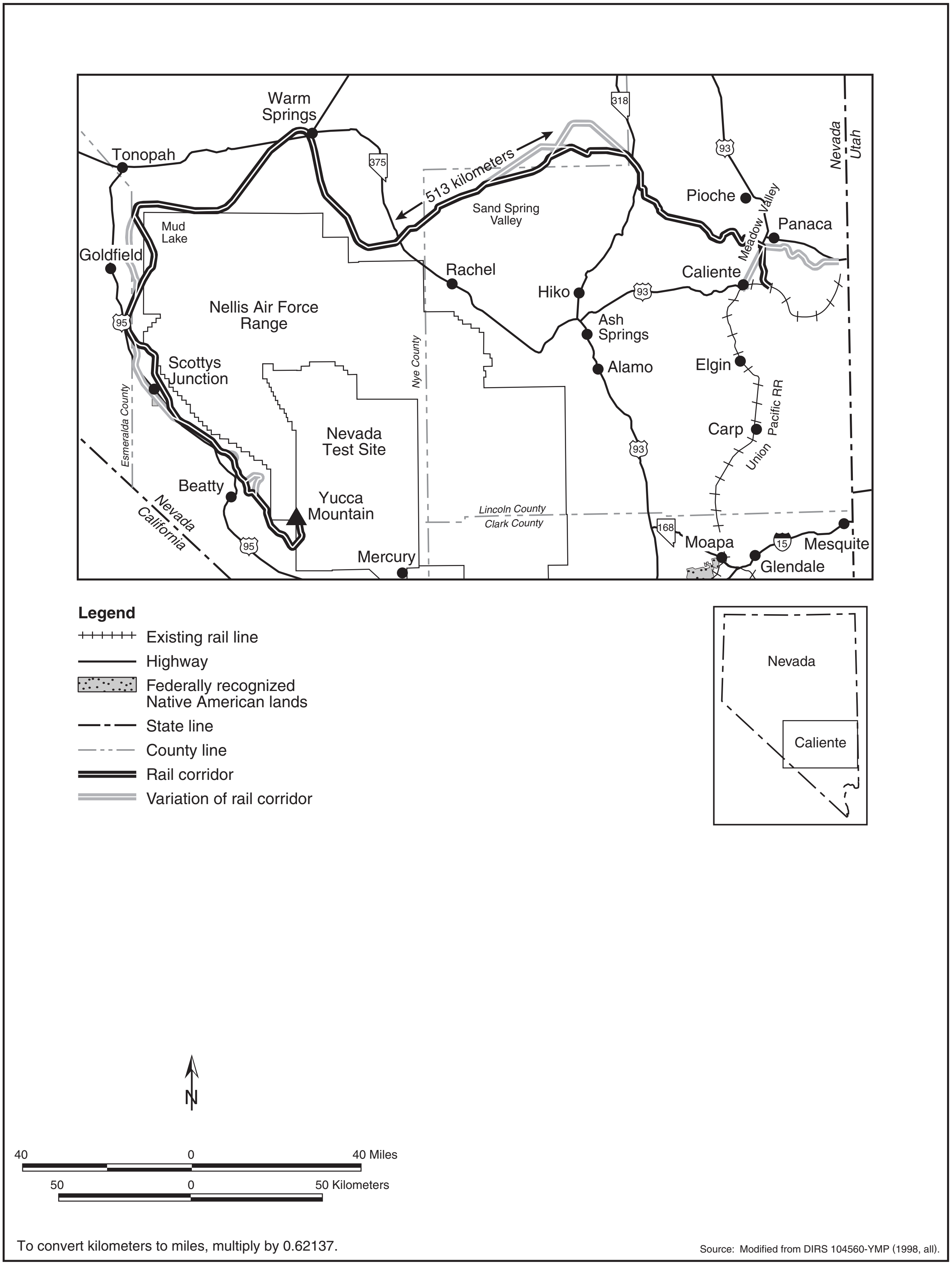


Figure 6-15. Caliente Corridor.

10 hours to travel from the junction with the Union Pacific mainline to a Yucca Mountain Repository on a Caliente branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Line Operations Plan). The estimated life-cycle cost of constructing and operating a branch rail line in the Caliente Corridor would be $880 million in 2001 dollars.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to air quality, aesthetics, and waste management would be the same as those described in Section 6.3.2.1 and are not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.1.1 Caliente Rail Land Use and Ownership

Table 6-23 summarizes the amount of land required for the Caliente corridor, its ownership, and the estimated amount of land that would be disturbed, as well as ranges for the variations. Table 6-24 summarizes the amount of land required for the Caliente Corridor variations and its ownership.

Table 6-23. Land use in the Caliente Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	513	512 - 553
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	205 (100)	205 - 221
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	188 (92)[e]	188 - 216
Air Force	10.9 (5.3)	0 - 10.9
DOE	4.6 (2.3)	4.6 - 4.6
Private	0.9 (0.46)	0.9 - 2.5
Tribal	None	0 - 1.6
Land area in 60-meter[f] right-of-way *(square kilometers)*	30.7	30.7 - 33.2
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	14.7	14.7 - 15.9
Outside 60-meter right-of-way	3.6	3.6 - 3.9

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. Percentages do not total 100 due to rounding.
f. 60 meters = 200 feet.

Construction. This corridor crosses several telephone, pipeline, highway, and power line rights-of-way, areas designated as available for sale or transfer, and oil and gas leases (DIRS 104993-CRWMS M&O 1999, Table 2, p. 10 and Table 3, p. 11). The corridor crosses Bureau of Land Management lands used for recreation, nine grazing allotments (Bennett Springs, Highland Peak, Black Canyon, Reveille, Ralston, Stone Cabin, Montezuma, Magruder Mountain, and Razorback), and seven wild horse and burro herd management areas. Section 6.3.2.1 discusses impacts common to all rail implementing alternatives. This section discusses impacts unique to a branch rail line in the Caliente Corridor.

The corridor passes just east of the Weepah Spring Wilderness Study Area and just north of the Worthington Mountains Wilderness Study Area. It also passes near the Kawich Wilderness Study Area and crosses a portion of the South Reveille Wilderness Study Area. The Kawich Area in the Kawich Range and the South Reveille Area in the Reveille Range and along Reveille Valley form a narrow corridor through which the Caliente Corridor passes. A portion of the Kawich and South Reveille Ranges have Bureau of Land Management Class II aesthetic classifications. Construction activities in the vicinity of a Wilderness Study Area could affect the experience in the wilderness environment. As indicated in Appendix J, Section J.3.1.2, the White River Alternate would be more distant from the Area. This route

Table 6-24. Possible variations in the Caliente Corridor.[a]

Variation	Length (kilometers)[b]	Land area in variation (square kilometers)[c]	Ownership in variation [square kilometers (percent)] Bureau of Land Management	Private	Tribal
Eccles Option	16.7	6.7	6.3 (95)	0.4 (5)	--[e]
Caliente Option	17.2	6.9	6.2 (90)	0.69 (10)	--
Crestline Option	37.8	15.1	14.5 (95.9)	0.6 (4.1)	--
White River Alternate	47.5	19	18.98 (99.9)	0.02 (< 0.1)	--
Garden Valley Alternate	37.7	15.1	15.1 (100)	0	--
Mud Lake Alternate	(f)	(f)	(f)	--	--
Goldfield Alternate	45.8	18.3	17.6 (96)	0.7 (4)	--
Bonnie Claire Alternate	42.2[g]	16.9	14.8 (87.4)	0.5 (3)	1.6 (10)
Oasis Valley Alternate	5.57	2.2	2.0 (89)	0.2 (11)	--
Beatty Wash Alternate	23.0	9.2	9.2 (100)	0	--

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.
d. NA = not applicable; length included in total corridor distance.
e. -- = none.
f. Mud Lake Alternate on Bureau of Land Management land included in other variations.
g. Includes 4.5 kilometers (2.8 miles) through Timbisha Shoshone Trust Lands.

variation would cross a small additional amount of private property. Impacts of constructing a branch rail line between the Kawich and South Reveille Areas would be less if DOE implemented Bureau of Land Management Class II requirements for building in these areas.

The Bonnie Claire Alternate of this corridor, in the vicinity of Scottys Junction, would pass through and bisect an 11.3-square-kilometer (2,800-acre) portion of the Timbisha Shoshone Trust Lands (DIRS 155930-Reynolds, Pool, and Abbey 2001, all). Bisecting this parcel could limit its proposed use, which includes tourism and housing for the Timbisha Shoshone.

If the Bonnie Claire Alternate was not used, the corridor would encroach on the Nellis Air Force Range (also known as the Nevada Test and Training Range). In addition, the Mud Lake Alternative would encroach on the Range. The U.S. Air Force has noted the potential for safety risks of crossing lands that are hazard areas and encompass weapons safety footprints for live weapons deployment. For each of the sections that could enter the Nellis Range, DOE has identified a corridor variation that would avoid the potential land-use conflict (see Appendix J, Section J.3.1.2).

If DOE decided to build and operate a branch rail line in the Caliente Corridor, it would consult with the Bureau of Land Management, the U.S. Air Force, and other affected agencies and Native American governments to help ensure that it avoided or mitigated potential land-use conflicts associated with the alignment of a right-of-way. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65, 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through any part of the Range.

The presence of a rail line could influence future development and land use along the railroad in the communities of Beatty, Caliente, Goldfield, Scottys Junction, and Warm Springs (that is, zoning and land use might differ depending on the presence or absence of a railroad), as well as a potential Timbisha Shoshone community at their Trust Lands parcel near Scottys Junction.

Operations. DOE expects operations along the Caliente Corridor to cause fewer impacts than the construction phase of the project.

The operation of a rail line in the vicinity of the Weepah Spring Wilderness Study Area could affect the experience of visitors to the Area. The White River Alternate would not pass near the Area, as indicated in Appendix J, Section J.3.1.2. The proximity of an operational rail line to the Kawich and South Reveille Wilderness Study Areas probably would affect these areas by drawing attention to the rail line during operational or maintenance activities.

The operation of a rail line along the Bonnie Claire Alternate could limit or potentially enhance economic development in the Timbisha Shoshone Trust Lands parcel and could limit the use for housing by restricting access. The alternate currently passes almost directly through the center of the parcel.

6.3.2.2.1.2 Caliente Rail Hydrology

Surface Water

Surface-water resources along the Caliente Corridor are discussed in Chapter 3, Section 3.2.2.1.3, and summarized in Table 6-25. The table indicates that the number of surface-water resources in the vicinity of the corridor could vary if DOE used corridor variations, but only by small numbers. In fact, the Caliente Corridor has the smallest number of nearby water resources with the possible exception of the Oasis Valley Alternate. This alternate would be farther away from one identified spring such that the spring's location would no longer be within the 400-meter (0.25-mile)-wide corridor. The spring would, however, still be within 1 kilometer (0.6 mile) of the corridor. As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface water, or the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Table 6-25. Surface-water resources along Caliente Corridor and its variations.[a,b,c]

	Resources in 400-meter[d] corridor			Resources outside corridor within 1 kilometer[e]		
Description	Spring	Stream/ riparian area	Reservoir	Spring	Stream/ riparian area	Reservoir
Caliente Corridor	1	3	--[f]	5	--	--
with Crestline Option	1	3	--	7	--	--
with Caliente Option	2	3	--	7	--	--
with Goldfield Alternate	1	3	--	7	--	--
with Oasis Valley Alternate	--	3	--	6	--	--

a. Source: reduced from tables in Chapter 3, Section 3.2.2.1.3.
b. Resources are the number of locations; that is, a general location with more than one spring was counted as one water resource.
c. Resources shown for variations are for the entire corridor with only the identified changes. Variations not listed (White River Alternate, Garden Valley Alternate, Mud Lake Alternate, Bonnie Claire Alternate, and Beatty Wash Alternate) are not associated with any identified water resources, nor would they avoid any resources along the corridor.
d. 400 meters = about 1,300 feet.
e. 1 kilometer = 0.6 mile.
f. -- = none.

Flood zones identified along the Caliente Corridor and its variations are listed in Table 6-26. As indicated in the table's footnotes, the 100-year flood zone information is summarized from Federal Emergency Management Agency maps, which provide coverage for about half the corridor's length. Based on the available data, this corridor would cross nine different 100-year flood zones or flood zone groups between its beginning near Caliente and when it enters the Nevada Test Site. None of the variations would change this number notably. Use of the Crestline Option would decrease the number of flood zones by one, and the other applicable variations would leave the number unchanged or increased by one. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Table 6-26. 100-year flood zones crossed by the Caliente Corridor and its variations.[a,b]

Rail corridor portion	Crossing distance (kilometers)	Flood zone feature(s)	Avoided by variation (Yes or No)
Eccles Siding to Meadow Valley	0.2[c]	Clover Creek (intermittent)	Y-1
	0.8[c]	Meadow Valley Wash (wet)	Y-1, 2
Meadow Valley Wash to Sand Spring Valley	0.5[c]	White River (intermittent)	N
Sand Spring Valley to Mud Lake	1.1	Unnamed drainage gully on FEMA map in East/Central Nye County; crosses twice (dry)	N
	17.5	Mud Lake basin and drainage tributaries (normally dry)	N
Mud Lake to Yucca Mountain	0.8	Unnamed washes to the north and south of Ralston (dry)	N
	0.3	Tolicha Wash (intermittent)	Y-7
	1.1	Amargosa River (wet in sections, intermittent in others)	Y-8
	0.1	Beatty Wash (intermittent)	Y-9
Variations			
1. Crestline Option	0.8	Crosses Meadow Valley Wash (wet)	
2. Caliente Option	0.8	Crosses Meadow Valley Wash (wet)	
	0.2	Crosses Clover Creek (intermittent)	
	0.9	Crosses Meadow Valley Wash (wet) three times, rail corridor runs adjacent to Meadow Valley Wash. Passes in and out of flood zone	
3. White River Alternative	None	Located to the north of the corridor	
4. Garden Valley Alternative	None	Located to the north of the corridor	
5. Mud Lake Alternative	3.1	Crosses a larger amount of the Mud Lake flood zone (3.1 kilometers vs. 1.8 kilometers for the corridor)	
6. Goldfield Alternative	None	Located to west of corridor.	
7. Bonnie Claire Alternative	1.3	Crosses an unnamed wash south of Ralston	
	0.7	Crosses Tolicha Wash (intermittent)	
8. Oasis Valley Alternative	1.0	Crosses Amargosa River (wet in segments, intermittent in others)	
9. Beatty Wash Alternative	0.1	Crosses Beatty Wash (intermittent)	

a. Areas where natural floodwater movement might be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Lincoln and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).

b. About 47 percent of the Caliente Corridor is not available on maps, due primarily to limited coverage in Lincoln County, the Nellis Air Force Range, and the Nevada Test Site.

c. Projected from limited data. The specific area is not covered by Federal Emergency Management Agency maps; values were extrapolated from the closest maps.

d. Certain 100-year flood zones can be avoided by alternate corridor segments. These are identified with a “Y” (yes) and a number representing the specific variations from the second half of the table that avoids the specific flood zone. The same flood zone could be crossed by the corridor and its variations at different locations. In such cases, the feature will be marked “Avoided” for the corridor, but will appear again for the variation.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (see Chapter 3, Section 3.2.2.1.3, for estimated perennial yields for the hydrographic areas over which a branch rail line in the Caliente Corridor would pass).

HYDROGRAPHIC AREA

The Nevada Division of Water Planning has divided the State into groundwater basins, or *hydrographic areas*. These areas are used in the management of groundwater resources. Hydrographic areas are generally based on topographic divides (that is, they typically comprise a valley, a portion of a valley, or a terminal basin), but can also be based on administrative divisions. The State classifies a hydrographic area as a Designated Groundwater Basin when the permitted water rights (or appropriations) approach or exceed the area's estimated perennial yield and the water resources are depleted or require additional administration. The Division of Water Planning's home page *http://www.state.nv.us/cnr/ndwp* identifies the hydrographic areas that are Designated Groundwater Basins.

The amount of water needed for the construction of a branch rail line in the Caliente Corridor for soil compaction, dust control, and workforce use would be about 880,000 cubic meters (710 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 64 wells installed along the rail corridor. The average amount of water withdrawn from each well would be approximately 14,000 cubic meters (11 acre-feet). Most (91 percent) of the water need would be for use in the compaction of fill material. The estimate of fill quantities needed for construction would change if variations were used. However, no single variation applicable to the Caliente Corridor would increase the estimate of water demand by more than 5 percent.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the Caliente rail corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting water resources or requiring additional administration. Table 6-27 summarizes the status of the hydrographic areas associated with the Caliente Corridor and the approximate portion of the corridor that would pass over Designated Groundwater Basins. Use of corridor variations would make no notable difference in the portion of the corridor that crosses Designated Groundwater Basins.

Table 6-27. Hydrographic areas along Caliente Corridor and its variations.

		Designated Groundwater Basins	
Corridor description	Hydrographic areas	Number	Percent of corridor length
Caliente Corridor	17	6	40
Variations[a]	16 to 18	6	40

a. Several of the variations would involve small changes in the hydrographic areas crossed or the crossing distances. However, all (Caliente Option, Crestline Option, White River Alternate, Garden Valley Alternate, Mud Lake Alternate, Goldfield Alternate, Bonnie Claire Alternate, and Oasis Valley Alternate) would cross the same six Designated Groundwater Basins which, rounded to the nearest 10 percent, would represent the same portion of the total corridor.

The withdrawal of about 14,000 cubic meters (11 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente Corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 64 wells along the corridor would mean that many hydrographic areas would have multiple wells. As Table 6-27 indicates, about 40 percent of the corridor length would be over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Caliente Corridor would require about 47,000 tanker-truck loads of water or about eight truckloads each day for each work camp along the corridor. Again, water obtained from permitted sources, which would be within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. There would be no changes in recharge beyond those at the completion of construction.

6.3.2.2.1.3 Caliente Rail Biological Resources and Soils

Construction. The construction of a rail line in the Caliente Corridor including possible variations (see Appendix J, Section J.3.1.2) would disturb approximately 18 square kilometers (4,500 acres) of land (Table 6-23). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. Areas within 12 of the land-cover types identified in the State of Nevada (DIRS 104593-CRWMS 1999, pp. C1 to C5) would be affected by construction of a branch rail line in the Caliente Corridor (see Table 6-28). The greatest amounts of disturbance would occur in the salt desert scrub and sagebrush land-cover types, but would involve less than 0.001 percent of the existing area of Nevada in those land-cover types. The 0.001 fraction that would be disturbed for each cover type would be very small. The disturbance would have no discernible impact on the availability of habitat in any cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to the unvaried corridor.

Table 6-28. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Caliente Corridor.[b,c]

Land-cover type	ercent of corridor length	Area disturbed	Area in Nevada	Percent disturbed
Agriculture	0.3	0.05	5,200	0.001
Blackbrush	0.1	0.02	9,900	<0.001
Creosote-bursage	6.0	1.1	15,000	0.007
Grassland	0.2	0.04	2,800	0.001
Greasewood	0.4	0.07	9,500	<0.001
Hopsage	2.0	0.36	630	0.06
Juniper	0.3	0.05	1,400	0.003
Mojave mixed scrub	4.5	0.82	5,600	0.01
Pinyon-juniper	0.0	0	15,000	0.00
Playa	0.1	0.02	7,000	<0.001
Sagebrush	30	5.4	67,000	0.01
Sagebrush/grassland	0.3	0.05	52,000	<0.001
Salt desert scrub	56	10	58,000	0.02
Urban		ND[d]	2,400	ND

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.

About 50 kilometers (31 miles) along the southern end of the corridor, including variations in this area, is in desert tortoise habitat. Assuming that a maximum of about 0.06 square kilometer (15 acres) of land would be disturbed for each kilometer of rail line in this area, construction activities would disturb as much as 3 square kilometers (740 acres) of desert tortoise habitat, none of which is classified as critical habitat. In addition, these activities could kill individual desert tortoises; however, their abundance is low in this area (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O’Farrell 1998, pp. 407 to 411) so losses would be few. Relocation of tortoises along the route prior to construction would minimize losses of individuals. The presence of the branch rail line could interfere with the normal movements of individual tortoises. DOE would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) regarding this species if it selected this corridor and would implement all terms and conditions required by the Fish and Wildlife Service.

Although the southwestern willow flycatcher occurs near some portions of the corridor, including the variations, there is no suitable habitat of dense riparian vegetation for this Federally endangered species in the Caliente Corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

The only other Federally listed species near the corridor and its variations is the Railroad Valley springfish (Federally threatened), which has been found about 3 kilometers (1.9 miles) north of the corridor, and it should not be affected. The Eccles, Crestline, or Caliente variations of this corridor cross a portion of the Meadow Valley Wash, which is habitat for an unnamed subspecies of the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker, both of which are sensitive species. Construction of a branch rail line in this corridor could temporarily affect populations of these fish by increasing the sediment load in the wash during construction. Four other special status species occur along this corridor and its variations but could be avoided during land-clearing activities (DIRS 104593-CRWMS M&O 1999, p. 3-23) and, therefore, would not be affected.

One population of the Nevada sanddune beardtongue, a sensitive plant species, occurs within the 400-meter (0.25-mile) corridor and could be directly or indirectly affected by land-clearing activities and construction of the branch rail line. The location of this population would be identified through surveys before these activities, and disturbance of the plants would be avoided if possible.

In addition, there are six known populations of four sensitive plant species outside the 400-meter (0.25-mile) corridor, but within 5 kilometers (3 miles). Several additional populations of these four species and one other sensitive plant species occur within 5 kilometers of one or more of the variations listed in Appendix J, Section J.3.1.2. One population of one species (Needle Mountain milkvetch) outside the 400-meter corridor would be avoided by the Caliente Option and three populations of this species would be avoided by the Crestline Option. DOE anticipates that corridor activities would not affect these populations because land disturbance would not extend to these areas and changes would be unlikely in the aquatic or soil environment as a result of construction or the long-term presence of a railroad.

The rail corridor crosses 15 areas designated as game habitat and 8 areas designated as wild horse and burro management areas (see Chapter 3, Section 3.2.2.1.4). Construction activities would reduce habitat in these areas. Depending on the variation, several other designated game habitat areas could be within 5 kilometers (3 miles) of a rail line in the Caliente Corridor. Wild horses, burros, and game animals near these areas during construction would be disturbed and their migration routes could be disrupted.

At least one group of springs and three stream or riparian areas are within the 400-meter (0.25-mile) corridor including its variations (Table 6-26). Although formal delineations have not been made, these springs and riparian areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. In addition, the corridor, including its variations, crosses a number of ephemeral streams that could be classified as waters of the United States. DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary. DOE anticipates some changes to local drainage along a branch rail line, and would design the rail line to accommodate existing drainage patterns.

In addition, as many as 25 known springs and riparian areas occur outside of the 400-meter (0.25-mile) corridor, but within 5 kilometers (3 miles) of the corridor, including its variations. Eight known populations of three sensitive animal species are associated with these aquatic resources. DOE anticipates that corridor activities would not affect these populations because land disturbance would not extend to these areas and these areas would not be disturbed during the construction or long-term presence of a railroad.

Construction activities would temporarily disturb about 18 square kilometers (4,500 acres) of soils in and adjacent to the corridor. The impacts to soils of disturbing 18 square kilometers along the 513-kilometer- (319-mile)-long corridor would be transitory and small. However, several soil characteristics could influence construction activities and the amount of disturbed area. Soils susceptible to water or wind erosion occur along much of the corridor and its variations as do soils exhibiting relatively high shrink-swell characteristics (see Chapter 3, Section 3.2.2.1.4). Disturbance of erodible soils could lead to increased silt loads in water courses or increased soil transport by winds. Erosion control during construction and revegetation, or other means of soil stabilization after construction, would minimize these concerns. The presence of soils with poor (that is, high) shrink-swell characteristics could influence the amount of disturbed area if soils from outside areas were brought in for replacement or mixing with the native soil.

As stated in Chapter 3, Section 3.2.2.1.4, the variations identified for the Caliente Corridor could avoid some biological resources, as listed in Table 6-29.

Table 6-29. Biological resources avoided by Caliente Corridor variations.[a]

	Occurrence of resource			
	For unvaried segment of corridor		Occurrence avoided by variation	
Alignment variation resource	In corridor[b]	Within 5 km[c]	In corridor	Within 5 km
Caliente variation[d]				
Sensitive species–Needle Mountain milkvetch	0	3	0	1
Springs or groups of springs	4	24	0	1
Crestline variation				
Sensitive species–Needle Mountain milkvetch	0	3	0	3
Springs or groups of springs	4	24	0	4

a. The only corridor variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25-mile)], but avoided by the corridor variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the corridor variation.
d. Appendix J, Section J.3.1.2, lists variations for the Caliente Corridor implementing alternative.

6.3.2.2.1.4 Caliente Rail Cultural Resources

Construction. Site file searches for the Caliente Corridor and its variations (see Appendix J, Section J.3.1.2) yielded 97 recorded archaeological sites, 36 of which are either potentially eligible or have not been fully evaluated for the *National Register of Historic Places* (Chapter 3, Section 3.2.2.1.5). If DOE selected this corridor, it would conduct on-the-ground surveys of the 400-meter (0.25-mile)-wide corridor before and during construction activities to determine if construction of a branch rail line in this corridor could disturb sites or crush artifacts at archaeologic and historic sites.

At various points along the route, the Caliente Corridor and its variations intersect physical vestiges of historic railroads, including the Caliente and Pioche, Tonopah and Goldfield, and Las Vegas and Tonopah Railroads. The corridor also intersects the 1849 Jayhawker Emigrant Trail in Lincoln and Nye Counties. It passes close to three *National Register of Historic Places* properties—the Union Pacific Depot in Caliente (Caliente variation), the Tonopah Multiple Resource Area, and the Goldfield Historic District (Goldfield variation). However, the corridor and its variations passes these resources at a distance where adverse impacts would be unlikely. Southeast of Tonopah, the route passes through the former bombing range of the World War II Tonopah Army Air Station. Features related to that activity would be likely to occur on the landscape, but precise identification would not be possible until the completion of a cultural resource field inventory.

No areas or properties of interest to Native Americans have been identified and field-verified in the Caliente Corridor or its variations. However, the proposed right-of-way is near several potentially significant areas, including the Wild Horse and Willow Springs vicinity east of Goldfield (Caliente Corridor and Goldfield variation), the Oasis Valley north of Beatty (Oasis Valley Alternate), Crater Flat, and the Busted Butte-Fortymile Canyon area near the repository (DIRS 155826-Nickens and Hartwell 2001, all). In addition, the Bonnie Claire Alternate of the Carlin and Caliente Corridors passes through the land at Scottys Junction recently transferred to the Timbisha Shoshone Tribe.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.1.5 Caliente Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Caliente branch rail line would be small. The analysis evaluated the potential for impacts in terms of total reportable cases of injury and illness, lost workday cases, and fatality risks to workers and the public from construction and operation activities. Table 6-30 lists these results.

Table 6-30. Impacts to workers from industrial hazards during rail construction and operations in the Caliente Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	110	95
Lost workday cases	55	52
Fatalities	0.2	0.3
Noninvolved workers		
Total recordable cases	6.7	5.4
Lost workday cases	2.5	2.0
Fatalities	0.01	0.01
Totals[d]		
Total recordable cases	120	100
Lost workday cases	57	54
Fatalities	0.2	0.3

a. Totals for 46 months of construction.
b. Totals for 24 years of operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-31 lists these results.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Caliente Corridor. Table 6-32 lists the incident-free impacts, which include transportation along the Caliente Corridor and along railways in Nevada leading to a Caliente branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

6.3.2.2.1.6 Caliente Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction and operation of a branch rail line in the Caliente Corridor.

Construction. The length of the Caliente Corridor—513 kilometers (319 miles)—is the most important factor for determining the number of workers that would be required. To construct a branch rail line in this corridor would require workers laboring approximately 2.8 million hours or 1,410 worker years during the 46-month construction period (DIRS 154822-CRWMS M&O 1998, all). The route would require six construction camps to house workers temporarily.

Employment

DOE anticipates that total (direct and indirect) employment in the region of influence attributable to the Caliente branch rail line would peak in the first year of construction, 2006, at about 842 workers. Clark County would gain about 664 workers and Nye County would gain 101. The increase in employment

Table 6-31. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente Corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction			
Material delivery vehicles	20,000,000	0.3	0.04
Commuting workers	85,000,000	0.8	0.11
Subtotals	*100,000,000*	*1.2*	*0.15*
Operations			
Commuting workers	68,000,000	0.7	0.09
Totals	***170,000,000***	***1.9***	***0.24***

a. To convert kilometers to miles, multiply by 0.62137.

Table 6-32. Health impacts from incident-free Nevada transportation for the Caliente Corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	810	850
Estimated LCFs[c]	0.02	0.32	0.34
Public			
Collective dose (person-rem)	7	12	19
Estimated LCFs	0.003	0.01	0.01
Estimated vehicle emission-related fatalities	0.0016	0.0056	0.0071

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.
c. LCF = latent cancer fatality.

represents less than 1 percent of the baseline employment in Clark and Nye Counties. The additional 77 workers would represent a 3.2-percent increase of the employment baseline for Lincoln County. Changes in the Lincoln County level of employment would be the result primarily of indirect employment created by the presence of the transient construction workers.

Employment of Caliente Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth (2009 to 2010) of 15,240 jobs in the region of influence would be reduced by 827. The expected addition of 14,886 jobs in Clark County would be reduced by 788, and the expected growth of 330 jobs in Nye County would be reduced by 53. The expected growth of 24 jobs in Lincoln County would be supplemented by a net gain of 14. DOE anticipates that project-related workers not moving to Caliente Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in the region of influence associated with the construction of a Caliente branch rail line would peak in 2009 at about 822 persons. About 728 individuals would live in Clark County, 64 in Nye County, and 29 in Lincoln County. The estimated population increase attributable to the rail construction in the three counties is less than 1 percent of each county's population baseline. Because the change in population in relation to the population baseline would be small and transient, impacts to housing or schools would be unlikely.

Economic Measures

The expected peak annual changes in economic measures in the region of influence attributable to the Caliente Corridor would be increases of $24.3 million in real disposable income in 2009; $40.3 million in Gross Regional Product in 2007; and $2.8 million in State and local expenditures in the final year of construction, 2009. Clark County would generate more than 94 percent of the Gross Regional Product, experience more than 94 percent of the increase in real disposable income, and absorb more than 83 percent of the increase in expenditures by State and local governments. Nye and Lincoln Counties would share the remainder. (All dollar values in this section are in 2001 dollars unless otherwise stated).

Construction-related impacts to real disposable income, Gross Regional Product, and State and local government expenditures would be a less-than-1 percent increase for Clark and Nye Counties. Although the estimated increase in Lincoln County's Gross Regional Product would be about 1.6 percent of the baseline in 2006, increases in Gross Regional Product during the other years of construction. The increases in real disposable income would be about 1.2 percent in 2006 and less than 1 percent in other years. Increases in State and local government expenditures during all years of construction would be less than 1 percent from the County's baselines.

Transition and Operations Period. Employment opportunities associated with the construction of the branch rail line would probably dissipate at the project's completion and reduce the region's employment by 46 positions annually for 4 years. However, Nye County would have a net gain of 6 jobs and Lincoln County would have a net gain of 56 employment positions above the baseline. The additional job gain in Lincoln County represents a 2.2-percent average increase over the employment baseline in the referenced 4-year period. The employment gain in Nye County would be less than 1 percent. Constructing and operating a Caliente branch rail line would contribute to the growth in residential population throughout the transition period and to the employment base after 2013.

Employment and Population

Estimated annual direct employment for Caliente branch rail line operations would be 47 workers. Increased employment in the three counties comprising the region of influence would average about 79 jobs annually over the 24-year operations period (2010 to 2033). DOE anticipates that, on average, approximately 56 of these individuals would work in Lincoln County, representing a 2.1-percent increase of the employment baseline for Lincoln County. Increases in Clark and Nye Counties would be less than 1 percent of the baselines. In the region of influence, the average change to population because of a Caliente branch rail line would be about 351 additional people. DOE anticipates that approximately 95 individuals probably would choose to live in Lincoln County, an addition of 2 percent of the population baseline. The impact due to increases in population in Clark and Nye Counties would be much less than 1 percent of the applicable baseline. Because the impacts to population and employment would be so small in Clark and Nye Counties, impacts to housing or schools would be unlikely in either county. As discussed in Chapter 3, Section 3.1.7.4, Lincoln County has a low occupancy rate for housing; therefore, the impact to Lincoln County's housing market would be very small despite a 2-percent increase in population. The annual impact to schools in Lincoln County resulting from the increase in population would average about 22 additional pupils.

Economic Measures

Within the three-county region of influence, the estimated greatest annual increase above the baseline in real disposable income attributable to operations would occur in 2033, the last year of operation, and would be $6.2 million; annual increases during the 24 years of operation would average $5.2 million. Increases in Gross Regional Product would average about $4.5 million. As discussed above, the region would experience a slower growth in employment for several years. In the case of the Caliente branch rail line, on average during operation, changes in real disposable income would exceed changes in Gross Regional Product. Annual State and local government expenditures during operations, averaging $1.8 million, would be much lower than those reported above for construction. Impacts to real disposable income, Gross Regional Product, and State and local government expenditures from the operation of a Caliente branch rail line would be less than 1 percent of the baseline for Clark and Nye Counties.

In Lincoln County, the impact of the change to the baseline in real disposable personal income and in government spending would be to increase levels by averages of 1.6 percent and 2.4 percent, respectively, for the duration of operations. Changes to the Gross Regional Product would average 2.6 percent above the baseline. Workers associated with operation of a Caliente rail line would purchase many goods and services in Lincoln County. These dollars would continue to circulate largely in the area, creating a positive economic impact.

DOE performed detailed analyses for the Caliente Corridor branch rail line implementing alternative. The results of the analyses are representative of the potential variations listed in Appendix J, Section J.3.1.2.

In addition, DOE analyzed a sensitivity case that assumed all Lincoln County socioeconomic impacts would occur only in the City of Caliente. Under this assumption, City population would rise by 3 percent (29 persons) during construction and by 6.9 (67 persons) percent during operations. Employment would rise by about 5 percent during construction and about 7.2 percent during operations.

6.3.2.2.1.7 Caliente Rail Noise and Vibration

Over most of its length, the Caliente Corridor passes through undeveloped land managed by the Bureau of Land Management, where human inhabitants are mostly isolated ranchers and persons involved with outdoor recreation. The Towns of Caliente and Panaca are near or along the eastern end of the corridor. The Caliente variation for connecting to the Union Pacific Railroad mainline would follow an old railroad bed through the center of the Town of Caliente. Corridor variations (see Appendix J, Section J.3.1.2) with the exception of Caliente are close enough to the rail line for noise impacts to be significant (Table 6-33). Noise levels in Caliente would not differ much from existing background noise levels associated with normal rail traffic through the community. Noise levels associated with waste shipments would occur at most three times a day and probably not within any given hour. Where the branch rail line passed through Caliente, train speed would be reduced for safety and noise levels would be minimized. There is one traffic crossing in the Town of Caliente where traffic could be delayed. Adverse community response to the added rail noise would be unlikely because of the long-term presence of railroad traffic in Caliente, the short trains associated with transport of waste shipments, and the low frequency of rail trips to and from the Yucca Mountain site.

Table 6-33. Estimated propagation of noise from the operation of waste transport train using two locomotives in communities near the Caliente Corridor.

Community	Distance (kilometers)[a]	Estimated noise (dBA)[b]
Caliente Option		
Caliente	0	>90 at 15 meters[c]
Panaca	6[d]	26.0
Crestline Option		
Panaca	4.5[d]	26.3
Eccles Option		
Caliente	6.5[d]	<26[e]
Tonopah	12[d]	<26
Goldfield	6.2[d]	<26
Beatty	9.6[d]	<26
Beatty Wash Alternate		
Beatty	11.2[d]	<26
Amargosa Valley	9.6[d]	<26

a. To convert kilometers to miles, multiply by 0.62137.
b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
c. 15 meters = 49 feet.
d. Noise estimates at distances greater than 2 kilometers (1.2 miles) have large uncertainty.
e. At these distances, the A-weighted sound pressure level is dominated by lower frequencies (lower than 63 Hertz) and would not be distinguishable from normal background levels of noise.

In addition to passing near communities, the Caliente Corridor, including its variations, would pass through areas with farms and ranches. Some rural residences could fall within the region of influence for noise. The corridor, except the Caliente Option that would pass through Caliente, would be at least 4 kilometers (2.5 miles) from every town or community along its length. The noise from trains in these remote communities would not exceed daytime or nighttime noise standards for residential areas (60 or 50 dBA, respectively). Similarly, there would be little potential for noise impacts from construction and operation activities.

The estimated population residing within 2 kilometers (1.2 miles) of the Caliente Corridor in 2035 would be about 350 persons.

The Caliente Corridor would pass within 1.9 kilometers (1.2 miles) of the border of the Timbisha Shoshone Homeland. The Bonnie Claire Alternate would pass through 4.1 kilometers (2.5 miles) of the Timbisha Shoshone Trust Lands parcel near the intersection of State Route 267 and U.S. Highway 95. Noise levels from trains passing through the homeland would be 90 dBA at 15 meters (49 feet) for the Bonnie Claire Alternate. At the closest point of the Caliente Corridor, the estimated noise levels would be 44 dBA. Ethnographic responses to noise have not been determined (see Section 6.1.2.5). However, the noise levels associated with the Caliente Corridor would be lower than those associated with the Bonnie Claire Alternate.

Vibration. With the exception of the historic railroad station in Caliente, which is near the existing Union Pacific Railroad mainline, a branch rail line in the Caliente Corridor would be distant from historic structures, ruins, and buildings. Therefore, vibration impacts would be unlikely except at the Caliente Rail Station. However, the vibrations added by the relatively few trains carrying spent nuclear fuel and high-level radioactive waste at slow speeds through Caliente would not add appreciably to the vibrations to which the station is exposed from commercial train traffic. The small number of trips (two per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.1.8 Caliente Rail Utilities, Energy, and Materials

Table 6-34 lists the use of fossil fuel and other materials for the construction of a Caliente branch rail line.

Table 6-34. Construction utilities, energy, and materials for a Caliente branch rail line.

Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)[c]
510 - 550	42 - 45	870 - 940	72 - 78	420 - 460

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.2 *Carlin Corridor Implementing Alternative*

The Carlin corridor originates at the Union Pacific main line railroad near Beowawe in north-central Nevada. Figure 6-16 shows this corridor along with possible variations identified by engineering studies (DIRS 131242-CRWMS M&O 1997, all). The variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-16. With the exception of the differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the same among the possible variations.

The corridor travels south through Crescent, Grass, and Big Smoky Valleys, passing west of the City of Tonopah and east of the City of Goldfield. The corridor then travels south following and periodically

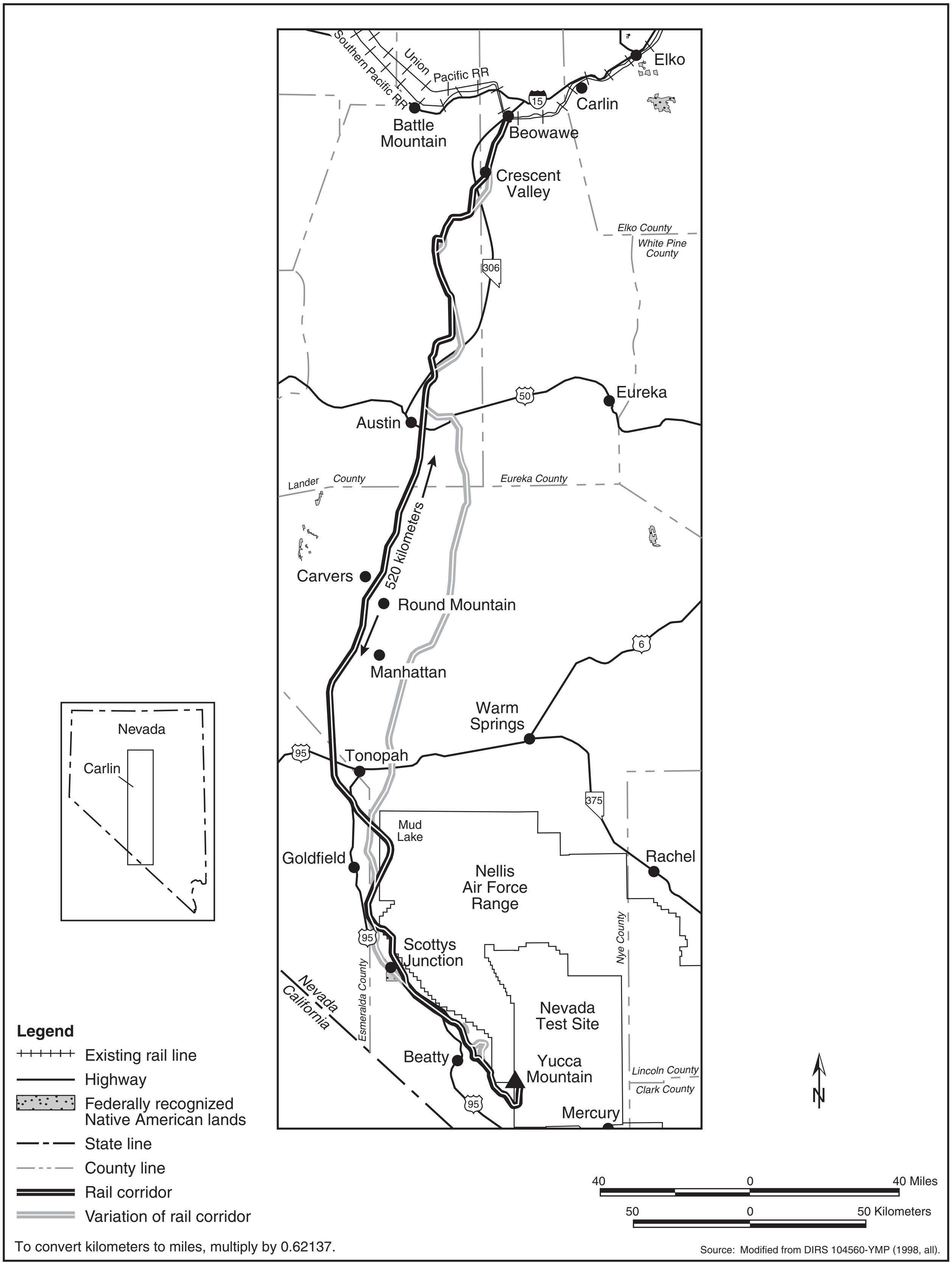


Figure 6-16. Carlin Corridor.

crossing the western boundary of the Nellis Air Force Range, passing through Oasis Valley and Beatty Wash. It travels along Fortymile Wash to the proposed repository location. The Carlin Corridor is about 520 kilometers (323 miles) long from its link with the Union Pacific line to the Yucca Mountain site. Variations of the route range from 513 to 544 kilometers (319 to 338 miles).

The construction of a branch rail line in the Carlin Corridor would require approximately 46 months. Construction would take place simultaneously at multiple locations along the corridor. DOE would establish an estimated five construction camps at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities. A train would take about 9 hours to travel from the junction with the Union Pacific mainline to the Yucca Mountain site on a Carlin branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Line Operations Plan). The estimated life-cycle cost to construct and operate a branch rail line in the Carlin Corridor would be about $821 million in 2001 dollars.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to air quality, aesthetics, and waste management would be the same as those common impacts discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.2.1 Carlin Rail Land Use and Ownership

Table 6-35 summarizes the amount of land required for the Carlin Corridor, its ownership, and the estimated amount of land that would be disturbed, as well as ranges for the variations. Table 6-36 summarizes the amount of land required for the Carlin Corridor variations and its ownership.

Table 6-35. Land use in the Carlin Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	520	513 - 544
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	208 (100)	205 - 218
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	179 (86)	177 - 201
Air Force	11 (5.2)	0 - 10.9
DOE	4.6 (2.2)	4.6 - 4.6
Private	14 (6.7)	7.3 - 15.2
Tribal	None	0 - 1.6
Land area in 60-meter[e] *right-of-way (square kilometers)*	31.2	30.8 - 32.6
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	17	16.7 - 17.7
Outside 60-meter right-of-way	2.3	2.2 - 2.4

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. 60 meters = 200 feet.

Construction. The Carlin Corridor crosses various telephone, highway, and utility rights-of-way. The corridor also crosses a Desert Land Entry withdrawal, 12 Bureau of Land Management grazing allotments (Carico Lake, Dry Creek, Grass Valley, Kingston, Simpson Park, Wildcat Canyon, Big Smoky, Francisco, San Antone, Montezuma, Magruder Mountain, and Razorback) and six wild horse and burro herd management areas. Other areas crossed by the corridor include the Bates Mountain antelope release area,

Table 6-36. Possible variations in the Carlin Corridor.[a]

Variation	Length (kilometers)[b]	Land area in variation (square kilometers)[c]	Ownership in variation [square kilometers (percent)]		
			Bureau of Land Management	Private	Tribal
Crescent Valley Alternate	24.4	9.8	7.2 (77)	2.3 (23)	--[d]
Wood Spring Canyon Alternate	11.7	4.7	4.7 (100)	0	--
Rye Patch Alternate	35.3	14.1	14.1 (100)	0	--
Steiner Creek Alternate	41.5	16.6	16.6 (100)	0	--
Big Smoky Valley Option	197	78.9	78.9 (100)	0	--
Monitor Valley Option	225.4	90.2	90.2 (100)	0	--
Mud Lake Alternate	(e)	(e)	(e)	--	--
Goldfield Alternate	43.1	18.3	17.6 (96)	0.7 (4)	--
Bonnie Claire Alternate	42.2[f]	16.9	14.3 (87)[g]	0.4 (3)	1.6 (10)
Oasis Valley Alternate	5.57	2.2	2.0 (89)	0.2 (11)	--
Beatty Wash Alternate	23.0	9.2	9.2 (100)	0	--

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.
d. -- = none.
e. Mud Lake Alternate included in other variations.
f. Includes 4.5 kilometers (2.8 miles) of Timbisha Shoshone Tribal land.
g. Includes 18 square kilometers (450 acres) of Timbisha Shoshone Tribal land.

three designated riparian habitats, and the Simpson Park habitat management area. It does not cross any oil or gas exploration and extraction areas. However, Bureau of Land Management lands are open to mineral and oil and gas exploration. The corridor passes through Bureau lands that are used for recreation, but does not pass through state or national forests. It does pass through areas adjacent to such facilities.

The construction of a branch rail line through Desert Land Entry withdrawal areas could affect the economic development of such properties by removing a portion of the lands and transferring it to DOE. If such property was divided, continued access to the property would be required. Construction impacts would be similar to those discussed in Section 6.3.2.1. As with the Caliente Corridor, the Bonnie Claire Alternate in the vicinity of Scottys Junction would pass through and divide an 11.3-square-kilometer (2,800-acre) portion of the Timbisha Shoshone Trust Lands (DIRS 155930-Reynolds, Pool, and Abbey 2001, all). The construction of a branch rail line in the Bonnie Claire Alternate could limit or potentially enhance economic development in the Timbisha Shoshone Trust Lands parcel and could limit the use for housing by restricting access.

The withdrawal of property from the private sector and the transfer of public lands would occur under existing government protocols. The withdrawal of lands from private ownership could impact area city and county economic expansion through the loss of tax revenues.

There are current mining operations in the Cortez Mine area of Crescent Valley. These operations, along with the historic mines in the area, make continued mining of this area a probability. Although the Carlin Corridor crosses no current leases, access through the valley could be affected for a short period during the construction of a branch rail line. The corridor also passes through areas of potential future exploration. The Crescent Valley Alternate (see Appendix J, Section J.3.1.2) passes just west of the Cortez Gold Mines. This corridor variation crosses an existing road right-of-way leading from the Gold Acres Mine to the ore mills at the Cortez mining facility. It also crosses a proposed pipeline right-of-way from the Cortez Gold Mine to the Dean Ranch. This pipeline would deliver water to the ranch (DIRS 155095-BLM 2000, all). Construction activities could deny or interfere with access to the milling facility at Cortez. The pipeline right-of-way would have to be modified to include DOE or the property rights would have to be transferred to DOE. Impacts to the road right-of-way would be slight if access to the area's mining facilities was maintained. The pipeline could require modifications to allow the building of a rail line through the right-of-way.

The Steiner Creek Alternate passes close to and might encroach on the Simpson Park Wilderness Study Area. Construction activities in the vicinity of a wilderness study area could affect the experience in the wilderness environment.

One segment of the Carlin Corridor and the Mud Lake Alternate would encroach on the Nellis Air Force Range (also known as the Nevada Test and Training Range). The U.S. Air Force has noted the potential for safety risks of crossing lands that are hazard areas and encompass weapons safety footprints for live weapons deployment. For each of the sections that could enter the Nellis Range, DOE has identified a corridor variation that would avoid the potential land-use conflict (see Appendix J, Section J.3.1.2). If DOE decided to build and operate a branch rail line in the Carlin Corridor, it would consult with the Bureau of Land Management, the U.S. Air Force, and other affected agencies and Native American governments to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a right-of-way. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65, 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through any part of the Range.

The presence of a rail line could influence future development and land use along the railroad in the communities of Austin, Beatty, Carver's Station, Cortez, Crescent Valley, Manhattan, Round Mountain, Scottys Junction, and Tonopah (that is, zoning and land use might differ depending on the presence or absence of a railroad), as well as a potential Timbisha Shoshone community at their Trust Lands parcel near Scottys Junction.

Operations. DOE expects operations along the Carlin Corridor, including its variations, to cause fewer impacts than the construction phase of the project, even though the branch rail line would pass through areas of private ownership and a number of other unique areas (see Table 6-2 in Section 6.1.2.1). The presence of an operational rail line near the Simpson Park Wilderness Study area could detract from the wilderness experience. The operation of a branch rail line along the Bonnie Claire Alternate could limit economic development in the Timbisha Shoshone parcel and could limit the parcel's use for reservation housing by restricting access. The Bonnie Claire Alternate passes almost directly through the center of the parcel.

6.3.2.2.2.2 Carlin Rail Hydrology

Surface Water

Surface-water resources along the Carlin Corridor and its variations are discussed in Chapter 3, Section 3.2.2, and summarized in Table 6-37. As listed in the table, the number of surface-water resources in the vicinity of the corridor would change by small numbers if DOE used any of the variations. Both the Rye Patch and Oasis Valley Alternates would involve one less surface-water resource in the 400-meter (0.25-mile)-wide corridor, and a corresponding increase in the number of resources outside the corridor but within 1 kilometer (0.6 mile). As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface waters, and the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Flood zones identified along the Carlin Corridor and its variations are listed in Table 6-38. The Federal Emergency Management Agency maps from which DOE derived the flood zone information provided coverage for about 83 percent of the corridor's length. This corridor would cross 11 different 100-year

Table 6-37. Surface water resources along Carlin Corridor and its variations.[a,b,c]

Corridor description	Resources in 400-meter[d] corridor			Resources outside corridor within 1 kilometer[e]		
	Spring	Stream/ riparian area	Reservoir	Spring	Stream/ riparian area	Reservoir
Carlin Corridor	1	5	--[f]	10	2	1
with Wood Spring Canyon Alternate	1	5	--	8	2	1
with Steiner Creek Alternate	1	5	--	10	1	1
with Rye Patch Alternate	1	4	--	11	3	1
with Monitor Valley Option	1	5	--	9	2	--
with Gold Field Alternate	1	5	--	12	2	1
with Oasis Valley Alternate	--	5	--	11	2	1

a. Source: Reduced from tables in Chapter 3, Section 3.2.2.1.3.
b. Resources are the number of locations; that is, a general location with more than one spring was counted as one water resource.
c. Resources shown for variations are for the entire corridor with only the identified variation changed. Variations not shown (that is, Crescent Valley Alternate, Mud Lake Alternate, Bonnie Claire Alternate, and Beatty Wash Alternate) are neither associated with any identified water resources, nor would they avoid any resources along the Corridor.
d. 400 meters = about 1,300 feet.
e. 1 kilometer = 0.6 mile.
f. -- = none.

flood zones or flood-zone groups before entering the Nevada Test Site. Eight of the 10 variations would change the number of flood zones crossed but, with one exception, changes would be up or down by one. The exception would be the Monitor Valley Option, which would increase the number of 100-year flood zones crossed by four. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (see Chapter 3, Section 3.2.2.1.3, for estimated perennial yields for the hydrographic areas over which the potential branch rail line in the Carlin Corridor passes).

The estimated amount of water needed for the construction of a branch rail line in the Carlin Corridor for soil compaction, dust control, and workforce use would be about 810,000 cubic meters (660 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 67 groundwater wells installed along the rail corridor. The average amount of water withdrawn from each well would be approximately 12,000 cubic meters (10 acre-feet). Most (91 percent) of the water would be used for compaction of fill material. The estimate of fill quantities for construction varies according to the variation. However, no single variation applicable to the Carlin Corridor would increase the estimate of water demand by more than 5 percent.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting water resources or requiring additional administration.
Table 6-39 summarizes the status of the hydrographic areas associated with the Carlin Corridor, and the approximate portion of the corridor that passes over Designated Groundwater Basins. As listed in Table 6-39, use of the Monitor Valley Option would result in an approximate 20-percent decrease in the portion of the corridor crossing Designated Groundwater Basins.

Table 6-38. 100-year flood zones crossed by the Carlin Corridor and its variations.[a,b]

Corridor portion	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (Yes or No)
Beowawe to Austin	4.0	Flood zone associated with Coyote Creek drainage (dry)	N
	1.6	Indian Creek (dry) and unnamed wash to the south	Y-1
	0.9	Unnamed Callaghan tributary, Skull and Callaghan Creeks (intermittent)	Y-3
	0.1	Rye Patch Canyon Creek (intermittent)	Y-4, 5
	1.4	Simpson Park Canyon Creek (intermittent) and Canyon Creek drainage (intermittent)	Y-4, 5
	1.4	Canyon Creek and Canyon Creek drainage (intermittent)	Y-5
Austin to Mud Lake	0.3	Peavine Creek tributary (intermittent)	Y-5
Mud Lake to Yucca Mountain	0.8	Unnamed washes to the north and south of Ralston (dry)	N
	0.3	Tolicha Wash	Y-8
	1.1	Amargosa River (wet in sections, intermittent in others)	Y-9
	0.1	Beatty Wash	Y-10
Variations			
1. Crescent Valley Alternate	2.0	Crosses Indian Creek (intermittent)	
	3.2	Crosses an unnamed wash to the south	
2. Wood Spring Alternate	None	Located to the west of the primary rail corridor	
3. Steiner Creek Alternate	4.9	Crosses Callaghan and Canyon Creeks (intermittent)	
4. Rye Patch Alternate	1.4	Crosses Canyon Creek and Canyon Creek drainage (intermittent)	
5. Monitor Valley Option[d]	0.6	Crosses Mosquito Creek (intermittent)	
	0.5	Crosses Corcoran Creek and Meadow Creek (intermittent)	
	1.5	Crosses Meadow Creek drainage; (dry)	
	0.6	Crosses Hunts Canyon Creek (intermittent)	
	0.2	Crosses Willow Creek (intermittent)	
	2.0	Crosses drainage areas approaching Mud Lake (dry)	
	5.7	Crosses drainage areas approaching Mud Lake (dry)	
	4.8	Crosses Mud Lake drainage (dry)	
6. Mud Lake Alternate	3.1	Crosses the Mud Lake flood zone	
7. Goldfield Alternate	None	Located to west of rail Corridor	
8. Bonnie Claire Alternate	1.3	Crosses an unnamed wash south of Ralston	
	0.7	Crosses Tolicha Wash (intermittent)	
9. Oasis Valley Alternate	1.0	Crosses Amargosa River (wet in segments, intermittent in others)	
10. Beatty Wash Alternate	0.1	Crosses Beatty Wash (intermittent)	

a. Areas where natural floodwater movement might be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Eureka, Lander, and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).

b. About 17 percent of the primary Carlin Corridor is not available on Federal Emergency Management Agency maps, due primarily to limited coverage in Esmeralda County, the Nellis Air Force Range, and the Nevada Test Site.

c. To convert kilometers to miles, multiply by 0.62137.

d. Certain 100-year flood zones can be avoided by alternate corridor segments. These are identified with a "Y" (yes) and a number representing the specific alternate(s) from the second half of the table that avoids the specific flood zone. The same flood zone might be crossed by the corridor and its variations at different locations. In such cases, the feature will be marked "Avoided" for the corridor, but will appear again for the variations.

Table 6-39. Hydrographic areas along Carlin Corridor and its variations.[a]

Corridor description	Hydrographic areas	Designated Groundwater Basins: Number	Designated Groundwater Basins: Percent of corridor length
Carlin Corridor	12	6	70
with Monitor Valley Option	12	5	50
with Goldfield Alternate	11	5	70
other alternates[a]	12	6	70

a. Crescent Valley, Wood Spring, Rye Patch, Steiner Creek, Mud Lake, Bonnie Claire, Oasis Valley, and Beatty Wash.

The withdrawal of about 12,000 cubic meters (10 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 67 wells along the corridor would mean that many hydrographic areas would have multiple wells. As indicated in Table 6-39, about 70 percent of the length of the Carlin Corridor is in Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. With such a large portion of the corridor over these basins, however, this would mean that DOE would truck water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation would ensure no adverse effects to groundwater resources. Use of the Monitor Valley Option would decrease the portion of the corridor crossing Designated Groundwater Basins and possibly increase DOE's flexibility in obtaining water along the corridor.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Carlin Corridor would require about 43,000 tanker-truck loads of water or about 9 truckloads each day for each work camp along the corridor. Again, water obtained from permitted sources, which would be within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

6.3.2.2.2.3 Carlin Rail Biological Resources and Soils

Construction. The construction of a rail line in the Carlin Corridor, including its variations, would disturb approximately 19 square kilometers (4,700 acres) (Table 6-35). Areas in nine of the land-cover types identified in Nevada (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5) would be affected by the construction of a branch rail line in the Carlin Corridor (Table 6-40). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. The EIS analysis assumed that the composition of land-cover types in these areas would be similar to the cover types in the corridor. The greatest amounts of disturbance would occur in the sagebrush, salt-desert scrub, and creosote bursage land-cover types for both the Big Smoky Valley Option and Monitor Valley Option, but would involve far less than 0.01 percent of the existing area in those land-cover types. The fraction disturbed for each cover type would be very small. The disturbance would have no discernible impact on the availability of habitat for plants or animals associated with any cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to that in the unvaried corridor.

About 50 kilometers (31 miles) of its length along the southern end of the corridor occurs in desert tortoise habitat. Assuming 0.06 square kilometer (15 acres) disturbed per linear kilometer of railroad, construction activities would disturb about 3 square kilometers (740 acres) of this habitat. Such activities could kill individual desert tortoises; however, the abundance of this species is low in this area (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411) so losses would be few. Relocation of tortoises along the corridor prior to construction would minimize losses of individuals. The presence of a branch rail line could interfere with movement of individual tortoises. If DOE selected this corridor, it would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) regarding this species, and would implement all terms and conditions required by the Fish and Wildlife Service.

Table 6-40. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Carlin Corridor.[b,c]

	Big Smoky Valley Option		Monitor Valley Option			
Land-cover type	Percent of corridor length	Land area	Percent of corridor length	Land area	Area in Nevada	Percent disturbed
Agriculture	0	0	0	0	5,200	0
Blackbrush	0.1	0.02	0.1	0.02	9,900	<0.001
Creosote-bursage	5.9	1.1	5.9	1.2	15,000	0.007
Grassland	0	0	0	0	2,800	0
Greasewood	6.4	1.2	4.3	0.86	9,500	0.013
Hopsage	1.9	0.37	1.9	0.38	630	0.057
Juniper	0	0	0	0	1,400	0
Mojave mixed scrub	4.5	0.87	4.5	0.9	5,600	0.015
Pinyon-juniper	0.6	0.12	0.6	0.12	15,000	<0.001
Playa	0	0	0	0	7,000	0
Sagebrush	24.9	4.8	43.1	8.7	67,000	0.012
Sagebrush/grassland	2.3	0.44	5.9	1.2	52,000	0.002
Salt desert scrub	53.4	10	33.7	6.8	58,000	0.018
Urban	ND[d]	ND	ND	ND	2,400	ND
Total[e]	100	19.3	100	20.1	250,000	N/A[f]

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.
e. Totals might differ from sums of values due to rounding.
f. N/A = not applicable.

Three other sensitive species occur in the 400-meter- (0.25-mile)-wide corridor: one population of a sensitive plant species, the Nevada sanddune beardtongue; and one population each of two sensitive animal species (a ferruginous hawk nesting area and the San Antonio pocket gopher). Use of the Monitor Valley Option rather than the Big Smoky Valley Option would avoid the pocket gopher population, and the Steiner Creek Alternate would avoid the hawk nesting area (Appendix J, Section J.3.1.2 lists corridor variations). These populations could be disturbed during construction activities. Adverse impacts to the hawk nesting area could be long term because periodic disturbances associated with the presence of a railroad could cause the hawks to abandon the area.

At least three populations of three sensitive plant species occur outside the corridor, but within 5 kilometers (3 miles). Use of the Monitor Valley Option would avoid one of these populations. DOE anticipates no impacts to these populations because land disturbance would not extend to these areas and changes in the aquatic or soil environment in these areas as a result of construction or long-term presence of a railroad would be unlikely.

Fourteen populations of eight sensitive animal species occur outside the corridor, but within 5 kilometers (3 miles). Ten populations of five of these species are associated with springs or aquatic habitat. These populations would not be affected by construction activities due to their distance from the corridor. The Monitor Valley Option would avoid one population each of two of these species.

This rail corridor, including its variations, crosses seven areas designated as game habitat and six areas designated as wild horse and burro management areas (see Chapter 3, Section 3.2.2.1.4). Construction activities would reduce habitat in these areas. Wild horses, burros, and game animals near these areas during construction would be disturbed, and their migration routes could be disrupted. In addition, there are 17 areas designated as game habitat outside the 400-meter (0.25-mile)-wide corridor but within 5 kilometers (3 miles). Larger game animals occupy large home ranges and could easily traverse the distance between the designated habitat and the proposed corridor. Four of these areas are associated with sage grouse (1 nesting and 3 strutting) and probably would not be affected by construction of the rail line.

One group of springs and three to four stream or riparian areas are within the 400-meter (0.25-mile)-wide corridor, and its variations (Table 6-37). Although no formal delineations have been made, these areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. In addition, the corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary. DOE anticipates some changes to local drainage along a branch rail line and would design the rail line to accommodate existing drainage patterns.

In addition, as many as 60 known springs and 6 riparian areas occur outside the corridor, but within 5 kilometers (3 miles), including the corridor variations. Nine known populations of four sensitive animal species are associated with these aquatic resources. DOE anticipates no impacts to these populations because these areas would not be disturbed during construction or by the long-term presence of a railroad. Although there are differences in the number of springs or riparian areas that some corridor variations would avoid, the Monitor Valley Option would avoid 13 of the springs and four of the riparian areas that are outside of the corridor but within 5 kilometers.

Construction activities would temporarily disturb about 19 square kilometers (4,700 acres) of soils in and adjacent to the corridor. The impacts to soils of disturbing 19 square kilometers (4,700 acres) along the 520-kilometer (323-mile)-long corridor would be transitory and small. However, several soil characteristics could influence construction activities and the amount of disturbed area. Soils susceptible to water or wind erosion occur along much of the corridor and its variations as do soils exhibiting relatively high shrink-swell characteristics (see Chapter 3, Section 3.2.2.1.4). Disturbance of erodible soils could lead to increased silt loads in water courses or increased soil transport by wind. Erosion control during construction, and revegetation or other means of soil stabilization after construction, would minimize these concerns. The presence of soils with poor (that is, high) shrink-swell characteristics could influence the amount of area disturbed by construction if soils from outside areas had to be brought in for replacement or mixing with native soil.

As stated in Chapter 3, Section 3.2.2.1.4, potential variations identified for the Carlin Corridor could avoid some biological resources, as listed in Table 6-41.

6.3.2.2.2.4 Carlin Rail Cultural Resources

Construction. This section discusses the segment of the Carlin Corridor from the existing Union Pacific main line railroad near Beowawe in north-central Nevada to its junction with the Caliente Corridor, northwest of Mud Lake. The remainder of the corridor is the same as the final segment of the Caliente Corridor from that point to the proposed repository; impact potential along that segment is discussed in Section 6.3.2.2.1.4.

Archaeological site file searches for the overall Carlin Corridor, including its variations (see Appendix J, Section J.3.1.2), resulted in the identification of 110 known sites (see Chapter 3, Section 3.2.2.1.5), 47 of which are eligible or potentially eligible for inclusion in the *National Register of Historic Places*. The segment of the Carlin Corridor north of the junction point with the Caliente Corridor crosses or passes through several potentially important areas for archaeological and historical sites. Based on currently available information (DIRS 155826-Nickens and Hartwell 2001, p. 27), each of the valleys through which the corridor and its variations pass—Crescent, Grass, Big Smoky, Monitor, and Ralston—have medium to high potential for prehistoric and historic Native American sites. Late 19th- and early 20th-century Western Shoshone village sites are collocated with the historic Grass Valley Ranch; similar situations might occur at other historic ranches the Corridor passes.

Table 6-41. Biological resources avoided by Carlin Corridor variations.[a]

Alignment variation resource	Occurrence of resource: For unvaried segment of corridor – In corridor[b]	Within 5 km[c]	Occurrence avoided by variation – In corridor	Within 5 km
Steiner Creek Variation				
Sensitive species–ferruginous hawk nesting	1	2	1	0
Game habitat–sage grouse strutting	2	3	1	1
Springs or groups of springs	4	59	0	2
Riparian areas	3	7	2	1
Rye Patch Variation				
Springs or groups of springs	4	59	1	0
Riparian areas	3	7	1	0
Monitor Valley Variation				
Sensitive species				
Big Smoky Valley speckled dace	0	1	0	1
Crescent Dune aegialian scarab	0	1	0	1
Nevada sanddune beardtongue	1	1	0	1
San Antonio pocket gopher	1	0	1	0
Game habitat				
Pronghorn–year round	1	0	1	0
Waterfowl	0	1	0	1
Springs or groups of springs	4	59	0	13
Riparian areas	3	7	0	4

a. Variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25 mile)], but avoided by the corridor variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the corridor variation.

Between Beowawe and U.S. Highway 50, the Carlin Corridor intersects with the California Emigrant Trail and the Pony Express Trail, both designated by Congress as *National Historic Trails* under the National Trails System Act, and the historic Pacific Telegraph Line, Butterfield Overland Mail and Stage route, and Lincoln Highway routes (DIRS 155826-Nickens and Hartwell 2001, p. 15). None of these resources has been evaluated for eligibility for the *National Register of Historic Places*, although the segment of the Pony Express Trail intersected by the Carlin Corridor, Rye Patch Alternate, and Monitor Valley Option has been designated a High Potential segment by the National Park Service. The Monitor Valley Option passes within view of the Belmont Historic District at the southern end of the valley, and to the south in Ralston Valley passes close to known but unrecorded and unevaluated archaeological sites, as well as the former bombing range for the Tonopah Army Air Station.

Construction of a branch rail line in this corridor could affect two historic Native American cemeteries, one in Crescent Valley and the other in Grass Valley (DIRS 155826-Nickens and Hartwell 2001, p. 27). The corridor passes within 3 kilometers (2 miles) of another cemetery southeast of Beowawe that local Western Shoshone families still use. Crescent Valley itself is part of the disputed Western Shoshone homelands, and grazing rights throughout the valley have been the subject of litigation between local Western Shoshone ranchers and the Bureau of Land Management.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.2.5 Carlin Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Carlin branch rail line would be small (see Table 6-42). The analysis evaluated the potential for impacts in terms of

Table 6-42. Impacts to workers from industrial hazards during rail construction and operations for the Carlin Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	99	95
Lost workday cases	49	52
Fatalities	0.14	0.26
Noninvolved workers		
Total recordable cases	5.9	5.4
Lost workday cases	2.2	2.0
Fatalities	0.006	0.006
Totals[d]		
Total recordable cases	110	100
Lost workday cases	51	54
Fatalities	0.14	0.27

a. Totals for 46 months for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities.

The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-43 lists these results.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Carlin Corridor. Table 6-44 lists the incident-free impacts, which would include transportation along the Carlin Corridor and transportation along railways in Nevada that led to a Carlin branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that would not have the capability to load rail casks while operational.

Table 6-43. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Carlin Corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	19,000,000	0.3	0.04
Commuting workers	76,000,000	0.8	0.10
Subtotals	*95,000,000*	*1.1*	*0.14*
Operations[c]			
Commuting workers	68,000,000	0.7	0.09
Totals	*160,000,000*	*1.8*	*0.23*

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 46 months for construction.
c. Totals for 24 years for operations.

Table 6-44. Health impacts from incident-free Nevada transportation for the Carlin Corridor.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	940	980
Estimated latent cancer fatalities	0.02	0.38	0.39
Public			
Collective dose (person-rem)	7	32	38
Estimated latent cancer fatalities	0.003	0.02	0.02
Estimated vehicle emission-related fatalities	0.002	0.017	0.018

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

6.3.2.2.2.6 Carlin Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction of a branch rail line in the Carlin Corridor and with the operation of the line.

The Carlin Corridor passes through Lander County, very small portions of Eureka and Esmeralda Counties, and Nye County. DOE considered potential socioeconomic impacts in Lander, Eureka, and Esmeralda Counties collectively as part of the Rest of Nevada, the portion of the State outside the region of influence.

Construction. The length of the Carlin Corridor, 520 kilometers (323 miles), would determine the number of workers required. The construction of a branch rail line in this corridor would require workers laboring for 2.5 million hours or 1,230 worker-years during the 46-month construction period (DIRS 154822-CRWMS M&O 1998, all). During the work week, the workers would commute to and temporarily live in five construction camps.

Employment

DOE anticipates that total (direct and indirect) employment in Nevada attributable to the construction of a Carlin branch rail line would peak in the first year of construction, 2006, at about 783 jobs, 85 percent of which would be in the region of influence. The increase in employment represents less than 1 percent of the baseline for employment in each of the three counties in the region of influence (Clark, Nye, and Lincoln Counties) and in the Rest of Nevada. Clark County would supply about 574 workers, Nye County 95, and Lincoln County 1. The balance of the workers, 113, would come from the Rest of Nevada. Employment of Carlin Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth of 19,915 jobs (2009 to 2010) in the State of Nevada would be reduced by approximately 700. The expected 14,886 additional jobs in Clark County would be reduced by 690, and the expected growth of 330 jobs in Nye County would be reduced by 46. The expected growth of 24 jobs in Lincoln County would be unaffected. The expected 4,675 additional jobs in the Nevada counties outside the region of influence would be supplemented by 37. DOE anticipates that project-related workers not moving to Carlin Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in Nevada attributable to the construction of a Carlin rail line, which would lag increases in employment, would peak 2 years later in 2009 at about 728 persons. About 683 persons, or 94 percent of the expected additional residents, would live in the region of influence. Clark County would gain about 625 residents, Nye County would gain about 57 residents, and Lincoln County would gain 1. The Rest of Nevada, would gain approximately 44 residents. Because Clark County has a larger population, the expected impact from the change in population would be less than 1 percent. The impacts of projected increases in population in Nye and Lincoln Counties, and in the Rest of Nevada would also be less than 1 percent. Because the increases in population resulting from the construction of a rail line in the Carlin Corridor would be small and transient in Clark, Nye, and Lincoln Counties, and in the Rest of Nevada, impacts to schools or housing would be unlikely.

Economic Measures

The expected peak annual changes in economic measures in the State due to the construction of a branch rail line in the Carlin Corridor would be increases of $21.4 million in real disposable income in 2009; $36.0 million in Gross Regional Product during 2007; and $2.5 million in State and local expenditures in 2009 with 90 percent concentrated in the region of influence. More than 90 percent of the increase in Gross Regional Product and real disposable income would be generated in Clark County. Clark County would absorb approximately 83 percent of the increases in State and local government expenditures. About 3 percent of the increase in Gross Regional Product and real disposable income would be generated in Nye County as would 7 percent of the expenditures by State and local governments. Because there would be virtually no change to employment or population in Lincoln County attributable to a rail line in the Carlin Corridor, there would be virtually no impact or change to Gross Regional

Product, real disposable income, or expenditures by State and local government. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Construction-related impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures for a branch rail line in the Carlin Corridor would be less than 1 percent of the applicable baselines for Clark, Nye, and Lincoln Counties and the Rest of Nevada.

Transition and Operations Period. In the period from 2010 to 2012, the State of Nevada would have an average of 27 fewer jobs. For perspective, the State of Nevada would have an average employment of about 1.5 million during this same period. Slightly slower growth would be confined to Clark County from 2010 to 2016. Growth in employment in Clark County during this transitional period would be approximately 66 fewer jobs than if DOE did not build a branch rail line in the Carlin Corridor. The Lincoln County employment baseline during this period would average about 75,000 jobs. During this period, Nye County would gain 5 jobs. There would be no change in employment in Lincoln County. A Carlin branch rail line would accelerate the rate of growth in the region's employment starting in 2016. The area outside the region of influence, the Rest of Nevada, would gain approximately 78 project-related jobs during this transition period. A Carlin rail line would contribute to growth in residential populations in and outside the region of influence throughout the transition period and to the employment base in the State after 2012.

Employment and Population

Estimated direct employment for operations in the Carlin Corridor would be 47 workers during the 24 years of operations. The change in total employment would average about 86 jobs in Nevada. DOE assumed that 6 of the additional workers would be employed in Clark County, about 6 in Nye County, and none in Lincoln County. The rest of the individuals would work in the Rest of Nevada, primarily in Elko County. The average annual addition to population in the State attributable to a branch rail line in the Carlin Corridor would be about 294 persons. About 160 of these persons would live in Clark County, 31 in Nye County, and none in Lincoln County. The rest of the individuals would live elsewhere within the State. DOE assumed that half of the Carlin rail operational personnel (approximately 24 directly employed individuals) would live at each end of the branch rail line. Rail operations employees and indirectly employed individuals who would live near the Beowawe end of the rail line would live in or near the Town of Elko in Elko County. Impacts due to changes in population and employment attributable to a Carlin rail line in Elko County, which had an estimated 2000 population of about 45,500 and about 21,100 jobs, would be less than 0.5 percent. Because impacts from increases in population and employment in each county would be small, impacts to schools or housing would be unlikely. The average annual impact, in relation to the baselines for population and employment in Clark, Nye, and Lincoln Counties and the Rest of Nevada, would be less than 1 percent.

Economic Measures

From 2010 until 2033 the estimated average annual increase in Nevada from operating a branch rail line in the Carlin Corridor in real disposable income would be $5.7 million. Approximately 33 percent would be generated in the region of influence, and the balance would be generated primarily in Elko County. The average increase in annual Gross Regional Product in the State attributable to a Carlin rail line would be about $5.3 million, of which $4.9 million would come from goods and services outside the region of influence. On average, during operation of a Carlin rail line, changes in real disposable income would exceed changes in Gross Regional Product. The increase in annual State and local government expenditures would be about $1.2 million, much lower than those reported above for construction. Approximately 46 percent of these additional expenditures would come from outside the region of influence. The impact of changes in Gross Regional Product, real disposable income, and expenditures by State and local governments would be less then 1 percent for Clark, Nye, and Lincoln Counties and for the Rest of Nevada.

DOE performed a detailed analysis for the Carlin rail line because of its length. The results of this analysis are representative of the potential variations (options and alternates) listed in Appendix J, Section J.3.1.2. The lengths of the variations are similar to those listed in Table 6-36.

6.3.2.2.2.7 Carlin Rail Noise and Vibration

Over most of its length, the Carlin Corridor, including the Monitor Valley and Big Smoky Valley Options, passes through undeveloped land managed by the Bureau of Land Management. Human inhabitants of this land consist primarily of isolated ranchers and persons involved with outdoor recreation. DOE identified 12 communities along or near the Carlin Corridor (including its Monitor Valley and Big Smoky Valley Options) and estimated the distances from a branch rail line to the community's nearest boundary (Table 6-45). The estimated maximum railroad noise from a two-locomotive train would occur at the boundary of the community. Estimated noise levels would not exceed the 60-dBA benchmark for residential communities during daytime hours. Communities within 1 kilometer (0.6 mile) of the rail line would experience single episodes of noise higher than the nighttime 50-dBA benchmark. A limitation of 10 dBA above the benchmark is allowable if its duration is less than 5 minutes in an hour (Washington Administrative Code-170-60). The estimated duration of noise that peaked at 57 dBA would be less than 2 minutes in communities 1 kilometer from the rail line at a speed of 50 kilometers (30 miles) per hour. For distances of 5 kilometers (3 miles) or greater, the estimate of 26 dBA would be subject to large uncertainty.

Table 6-45. Estimated propagation of noise (dBA) from the operation of a waste transport train with two locomotives in communities near the Carlin Corridor.

Corridor/community	Distance (kilometers)[a]	Estimated noise (dBA)[b]
Carlin Corridor		
Beowawe	3.2[c]	32
Crescent Valley	1.9	44
Austin	16	< 26
Big Smoky Valley Option		
Carver	1.0	57
Round Mountain	1.0	57
Manhattan	1.0	57
Monitor Valley Option		
Belmont	2.0	43
Tonopah (east alignment)	8[c]	< 26[d]
Tonopah (west alignment)	13[c]	< 26
Goldfield	6.0	< 26
Beatty	9.6[c]	< 26
Amargosa Valley	9.6[c]	< 26

a. To convert kilometers to miles, multiply by 0.62137.
b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
c. Noise estimates at distances greater than 2.0 kilometers (1.2 miles) have large uncertainty.
d. At these distances, the A-weighted sound pressure level is dominated by lower frequencies (lower than 63 Hertz) and would not be distinguishable from normal background levels of noise.

In addition to passing near communities, the variations of the Carlin Corridor pass through areas with farms and ranches. Therefore, some rural residences could fall in the region of influence for noise. The corridor and its 10 variations (see Appendix J, Section J.3.1.2) are at least 1 kilometer (0.6 mile) or more from every town along its length. The noise from trains would not exceed daytime noise standards for residential areas (60 dBA) more than 1 kilometer from a branch rail line. Because a Carlin rail line would pass near some communities, there would be a potential for noise impacts from both construction and operations. As discussed in Section 6.3.2.1, in areas where a branch rail line or variation passed near a community, train speeds could be limited to the extent necessary to ensure that noise was below levels listed in accepted noise standards.

The Carlin Corridor passes within 1.9 kilometers (1.2 miles) of the border of the Timbisha Shoshone Trust Lands parcel. The Bonnie Claire Alternate of the corridor passes through 4.1 kilometers (2.5 miles) of the Timbisha Shoshone Trust Lands parcel near the intersection of State Route 267 and U.S. Highway 95. Noise levels from trains passing through the parcel would be at 90 dBA at 15 meters (49 feet) for the Bonnie Claire Alternate. At the closest point of the Carlin Corridor, the estimated noise levels would be 44 dBA.

The estimated population residing within 2 kilometers (1.25 miles) of the Carlin Corridor in 2035 would be about 3,200 persons. The potential for human annoyance would be small.

Vibration. There are no known ruins of cultural significance along the Carlin Corridor. A branch rail line in the corridor or its variations would be distant from historic structures and buildings, so vibration impacts to such structures would be unlikely. The small number of trips (three per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.2.8 Carlin Rail Utilities, Energy, and Materials

Table 6-46 lists the projected use of fossil fuels and other materials in the construction of a Carlin branch rail line.

Table 6-46. Construction utilities, energy, and materials for a Carlin branch rail line.

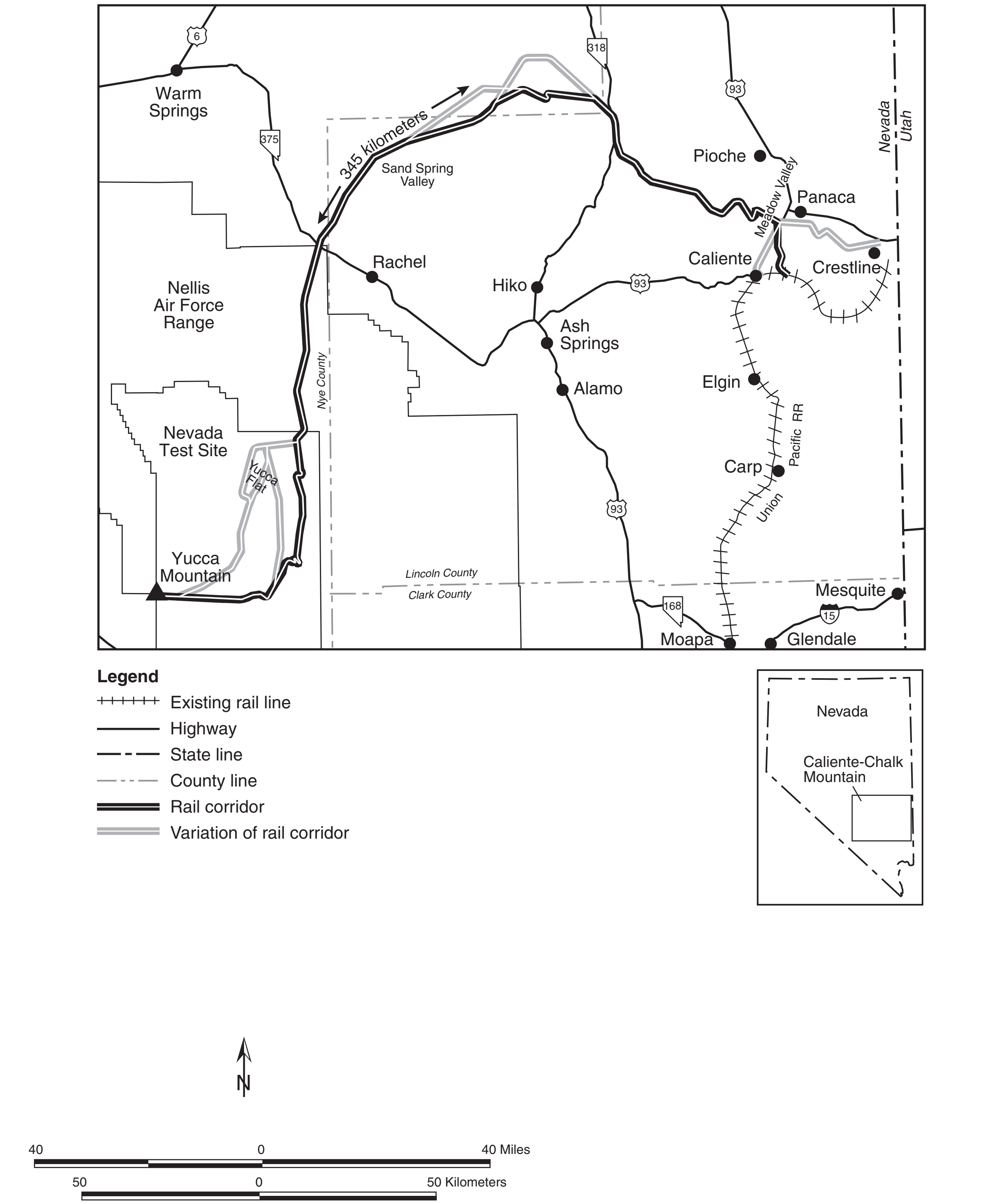
Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
510 - 540	39 - 41	790 - 840	71 - 75	400 - 420

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.3 *Caliente-Chalk Mountain Rail Corridor Implementing Alternative*

The Caliente-Chalk Mountain Corridor is identical to the Caliente Corridor until it reaches the northern boundary of the Nellis Air Force Range. At this point the Caliente-Chalk Mountain Corridor turns south through the Nellis Air Force Range and the Nevada Test Site to the Yucca Mountain site. Figure 6-17 shows this corridor along with possible variations identified by engineering studies (DIRS 154822-CRWMS M&O 1998, all). The corridor variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-17. With the exception of differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the same among the possible corridor variations. The corridor is 345 kilometers (214 miles) long from its link at the Union Pacific railroad near Caliente to Yucca Mountain. Variations of the route range from 340 to 380 kilometers (210 to 240 miles).

The construction of a branch rail line in the corridor would require approximately 43 months. Construction would take place simultaneously at a number of locations. An estimated four construction camps would be established at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities. A train would take about 8 hours to travel from the junction with the Union Pacific mainline to a Yucca Mountain Repository on a Caliente-Chalk Mountain branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Line Operations Plan). The estimated life-cycle cost to construct and operate a branch rail line in the Caliente-Chalk Mountain Corridor would be $622 million in 2001 dollars.



To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104560-YMP (1998, all).

Figure 6-17. Caliente-Chalk Mountain Corridor.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to air quality, aesthetics, and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.3.1 Caliente-Chalk Mountain Rail Land Use and Ownership

Construction. Table 6-47 summarizes the amount of land required for the Caliente-Chalk Mountain corridor, its ownership, and the estimated amount of land that would be disturbed. Table 6-48 summarizes the amount of land required for the Caliente-Chalk Mountain corridor variations and its ownership.

Table 6-47. Land use in the Caliente-Chalk Mountain Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	345	344 - 382
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	138 (100)	138 - 153
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	78 (56)[e]	77.4 - 88.5
Air Force	21.5 (16)	21.5 - 21.5
DOE	37.8 (27)	31.5 - 37.8
Private	0.8 (0.6)	0.8 - 1.1
Other	None	None
Land area in 60-meter[f] *right-of-way (square kilometers)*	20.7	20.6 - 22.9
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	9.6	9.6 - 10.6
Outside 60-meter right-of-way	3	3 - 3.4

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. Percentages do not total 100 due to rounding.
f. 60 meters = 200 feet.

The Caliente-Chalk Mountain Corridor would involve several road, power line, and utility rights-of-way before it entered the Nellis Air Force Range west of Groom Mountain and then the Nevada Test Site. The rights-of-way are similar to those discussed in relation to the Caliente Corridor and therefore the land-use impacts for this section of the corridor would be similar (see Sections 6.3.2.1 and 6.3.2.2.1). South of Rachel, Nevada the corridor crosses an additional road right-of-way (DIRS 104993-CRWMS M&O 1999, Table 5, p. 18). Variations of the corridor, as indicated in Appendix J, Section J.3.1.2, provide flexibility to address engineering, land use, or environmental constraints. Included are variations identified to provide flexibility to circumvent Test Site surface areas and associated facilities and radiologically contaminated areas. The corridor would also cross five oil and gas leases and three grazing allotments (Highland Peak, Bennett Springs, and Black Canyon). Many of the impacts along the Caliente-Chalk Mountain Corridor would be similar to those described for the Caliente Corridor (see Section 6.3.2.2.1) or are common to all five rail corridors as discussed in Section 6.3.2.1. The following paragraphs discuss impacts unique to the Caliente-Chalk Mountain Corridor.

Table 6-48. Possible variations in the Caliente-Chalk Mountain Corridor.[a]

Variation	Length (kilometers)[b]	Land area in variation (square kilometers)[c]	Land ownership [square kilometers (percent)]: Bureau of Land Management	Private	DOE
Eccles Option	16.7	6.7	6.3 (95)	0.4 (5)	--[e]
Caliente Option	17.2	6.9	6.21 (90)	0.69 (10)	--
Crestline Option	37.8	15.1	14.5 (95.9)	0.6 (4.1)	--
White River Alternate	47.5	19	18.98 (99.9)	0.02 (<0.1)	--
Garden Valley Alternate	37.7	15.1	15.1 (100)	--	--
Orange Blossom Road Option	85.9	34.4	--	--	34.4 (100)
Topopah Option	78.4	31.4	--	--	31.4 (100)
Topopah Option with Mine Mountain Alternate	77.8	31.1	--	--	31.1 (100)
Topopah Option with Area 4	72.1	28.8	--	--	28.8 (100)
Mercury Highway Option	52.3	20.9	--	--	20.9 (100)

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.
d. NA = not applicable; the Eccles Option and Orange Blossom Road Option lengths are included in the overall corridor length.
e. -- = none.

The Caliente-Chalk Mountain Corridor passes just east of the Weepah Springs Wilderness Study Area and just north of the Worthington Mountains Wilderness Study Area. The corridor involves land controlled by the Nellis Air Force Range (also known as the Nevada Test and Training Range) and, according to the Air Force, would affect Range operations. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65, 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through any part of the Range before DOE could build and operate this line.

Operations. DOE expects operations along the Caliente-Chalk Mountain Corridor to cause smaller impacts than the construction phase of the project.

The Air Force has identified national security issues related to a Chalk Mountain route (DIRS 104887-Henderson 1997, all), citing interference with Nellis Air Force Range testing and training activities. In response to Air Force concerns, DOE regards the route as a "non-preferred alternative."

6.3.2.2.3.2 Caliente-Chalk Mountain Rail Hydrology

Surface Water

Chapter 3, Section 3.2.2.1.3, discusses surface-water resources along the Caliente-Chalk Mountain Corridor; Table 6-49 summarizes these resources. The use of corridor variations could result in changes to the number of surface-water resources in the vicinity of the corridor. However, the changes would be primarily to the number of resources outside, but within 1 kilometer (0.6 mile), of the corridor. As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface waters, and the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Table 6-50 lists flood zones identified along the Caliente-Chalk Mountain Corridor and its variations. This corridor would cross at least three 100-year flood zones or flood-zone groups before entering the Nellis Air Force Range. Two of the four variations would change the number of flood zones crossed by one (up or down). The low number of flood zones identified for the Caliente-Chalk Mountain Corridor must be qualified by the fact that the Federal Emergency Management Agency maps, from which DOE

Table 6-49. Surface-water resources along Caliente-Chalk Mountain Corridor and its variations.[a,b,c]

Corridor description	Resources in 400-meter[d] corridor: Spring	Resources in 400-meter[d] corridor: Stream/ riparian area	Resources in 400-meter[d] corridor: Reservoir	Resources outside corridor within 1 kilometer[e]: Spring	Resources outside corridor within 1 kilometer[e]: Stream/ riparian area	Resources outside corridor within 1 kilometer[e]: Reservoir
Caliente-Chalk Mountain Corridor	--[f]	2	--	5	--	--
with Crestline Option	--	2	--	7	--	--
with Caliente Option	1	2	--	7	--	--
with Topopah Option	--	2	--	4	--	--
with Topopah-Area 4 Alternate	--	2	--	3	--	--
with Topopah-Mine Mountain Alternate	--	2	--	4	--	--

a. Source: Reduced from table in Chapter 3, Section 3.2.2.1.3.
b. Resources are the number of locations; that is, DOE counted a general location with more than one spring as one water resource.
c. Resources listed for variations are for the entire corridor with only the identified variations changed. Variations not listed (White River Alternate, Garden Valley Alternate, Mercury Highway Connection, Orange Blossom Road Option) are not associated with identified water resources, nor would they avoid resources along the corridor.
d. 400 meters = about 0.25 mile.
e. 1 kilometer = about 0.6 mile.
f. -- = none.

derived the flood zone information, provided coverage for only about 10 percent of the corridor length. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3, Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Caliente-Chalk Mountain Corridor passes).

The estimated amount of water needed for construction of a branch rail line in the corridor for soil compaction, dust control, and workforce use would be about 594,000 cubic meters (480 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 43 wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 14,000 cubic meters (11 acre-feet). DOE would use most (90 percent) of the water for compaction of fill material, and the estimate of fill quantities needed for construction would vary if the Department used variations. Use of either the Topopah or Mercury Highway Options on the Nevada Test Site would involve the largest increase in fill material and could increase the total water needed for this corridor by as much as 16 percent.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and if the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-51 summarizes the status of the hydrographic areas associated with the Caliente-Chalk Mountain Corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins. Use of the variations (Caliente Option, Crestline Option, White River Alternate, Garden Valley Alternate, Mercury Highway Option, Topopah Option, Mine Mountain Alternate, Orange Blossom Road Option, and Area 4 Alternate) would change the number of hydrographic areas crossed, but would have no effect on the portion of the corridor crossing Designated Groundwater Basins.

Table 6-50. 100-year flood zones crossed by the Caliente-Chalk Mountain Corridor and its variations.[a,b]

Corridor portion	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (yes or no)
Eccles Siding to Meadow Valley	0.2[e]	Clover Creek (intermittent)	Y-1
	0.8[e]	Meadow Valley Wash (wet)	Y-1,2
Meadow Valley Wash to Sand Spring Valley	0.5[e]	White River (intermittent)	N
Sand Spring Valley to Yucca Mountain	--[f,g]	Not available	
Variations			
1. Crestline Option	0.8	Crosses Meadow Valley Wash (wet)	
2. Caliente Option	0.8	Crosses Meadow Valley Wash (wet)	
	0.2	Crosses Clover Creek (intermittent)	
	0.9	Crosses Meadow Valley Wash (wet) three times, rail corridor runs adjacent to Meadow Valley Wash. Passes in and out of flood zone	
3. White River Alternate	None	Located to the north of the corridor	
4. Garden Valley Alternate	None	Located to the north of the corridor	
5. Topopah Option	--[g]	Located adjacent to corridor	
5a. Area 4 Alternate	--[g]	Variation along the Topopah Option	
5b. Mine Mountain Alternate	--[g]	Variation along the Topopah Option	
6. Mercury Highway Option	--[g]	Located adjacent to corridor	

a. Areas where natural floodwater movement might be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Lincoln and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).
b. About 91 percent of the Caliente-Chalk Mountain Corridor is not available on Federal Emergency Management Agency maps, due primarily to limited coverage in Lincoln County, the Nellis Air Force Range, and the Nevada Test Site.
c. To convert kilometers to miles, multiply by 0.62137.
d. Certain 100-year flood zones can be avoided by corridor variations. These are identified with a "Y" (yes) and a number representing the specific variation(s) that avoid the specific flood zone. The same flood zone might be crossed by both the corridor and variations at different locations. In such cases, the feature will be marked "Avoided" for the corridor route, but will appear again for the variations.
e. Projected from limited data. Specific area not covered by Federal Emergency Management Agency maps; values were extrapolated from the closest maps.
f. No information available on Federal Emergency Management Agency maps.
g. Limited information due to the Nellis Air Force Range or the Nevada Test Site.

Table 6-51. Hydrographic areas along Caliente-Chalk Mountain Corridor and its variations.

Description	Hydrographic areas	Designated Groundwater Basins	
		Number	Percent of corridor length
Caliente-Chalk Mountain Corridor	11	2	30
Variations[a]	10 to 12	2	30

a. Several of the variations would involve small changes in the hydrographic areas crossed or the crossing distances. However, all (Caliente Option, Crestline Option, White River Alternate, Garden Valley Alternate, Mercury Highway Option, Topopah Option, Mine Mountain Alternate, Orange Blossom Road Option, and Area 4 Alternate) would cross the same two Designated Groundwater Basins. Rounded to the nearest 10 percent, this would represent the same portion of the total corridor.

The withdrawal of about 14,000 cubic meters (11 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 43 wells along the corridor would mean that many hydrographic areas would have multiple wells. As listed in Table 6-51, about 30 percent of the corridor length is over

Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use well locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources did not receive adverse impacts.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Caliente-Chalk Mountain Corridor would require about 32,000 tanker-truck loads of water or about eight truckloads each day for each work camp area along the corridor. Again, water obtained from permitted sources, which would provide water in allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

6.3.2.2.3.3 Caliente-Chalk Mountain Rail Biological Resources and Soils

Construction. The construction of a branch rail line in the Caliente-Chalk Mountain Corridor, including potential variations, would disturb about 12 square kilometers (3,000 acres) of land (Table 6-47). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. Areas in eight of the land-cover types identified in Nevada (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5) would be affected (Table 6-52). The greatest amounts of disturbance would occur in the salt desert scrub, sagebrush, and blackbrush land cover types, but would involve far less than 0.01 percent of the existing area in those types. The fraction disturbed for each cover type would be very small. The disturbance would have no discernable impact on the availability of habitat for plants or animals associated with any cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to the unvaried corridor.

About 40 kilometers (25 miles) of the corridor length at its southern end, including potential variations, crosses desert tortoise habitat. Assuming that 0.06 square kilometer (15 acres) would be disturbed for each linear kilometer of railroad, construction activities would disturb as much as 2.4 square kilometers (590 acres) of desert tortoise habitat, some of which is classified as critical habitat. Such activities could kill individual desert tortoises; however, their abundance is low in this area (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411) so losses would be few. The presence of a branch rail line could interfere with movements of individual tortoises. Relocation of tortoises along the corridor prior to construction would minimize losses of individuals. If DOE selected this corridor, it would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) in relation to this species and would implement all terms and conditions required by the Fish and Wildlife Service.

Although the southwestern willow flycatcher occurs near some portions of the Caliente-Chalk Mountain Corridor, there is no suitable habitat of dense riparian vegetation for this listed endangered species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

The Eccles, Crestline, and Caliente variations for this corridor cross a portion of the Meadow Valley Wash, which is habitat for an unnamed subspecies of the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker, both of which are sensitive species (see Chapter 3, Section 3.2.2.1.4). The construction of a branch rail line near Caliente could temporarily affect populations of these fish by increasing the sediment load in the wash during construction. Three special status plant

Table 6-52. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Caliente-Chalk Mountain Corridor.[b,c]

Land cover type	Percent of corridor length	Area disturbed	Area in Nevada	Percent disturbed
Agriculture	0.5	0.05	5,200	0.01
Blackbrush	24.8	2.45	9,900	0.02
Creosote-bursage	0.0	0	15,000	0
Grassland	0.4	0.04	2,800	0.001
Greasewood	0.0	0	9,500	0
Hopsage	1.9	0.19	630	0.03
Juniper	0.0	0	1,400	0
Mojave mixed scrub	2.4	0.24	5,600	0.004
Pinyon-juniper	0.0	0	14,700	0
Playa	0.0	0	7,000	0
Sagebrush	30.1	3	67,000	0.004
Sagebrush/grassland	0.4	0.04	52,000	<0.001
Salt desert scrub	39.3	3.89	58,000	0.007
Urban		ND[d]	2,400	ND

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.

species are found along this corridor and its variations but could be avoided during land-clearing activities and would not be affected.

At least 40 populations of five sensitive plant species occur outside the 400-meter (0.25-mile)-wide corridor, but within 5 kilometers (3 miles) of the corridor. Several other populations of three other sensitive plant species occur within 5 kilometers of one or more of the corridor variations listed in Appendix J, Section J.3.1.2. DOE anticipates that these populations would be unaffected because land disturbance would not extend to these areas and changes in the aquatic or soil environment in these areas as a result of construction or the long-term presence of a railroad would be unlikely.

This rail corridor, including variations, would cross seven areas designated as game habitat and two areas designated as wild horse or wild horse and burro management areas. Construction activities would reduce habitat in these areas. Depending on the variation, several other designated game habitat areas could be within 5 kilometers (3 miles) of a rail line in the corridor. Game animals, burros, and horses near areas of active construction would be disturbed and their migration routes could be disrupted.

Two stream or riparian areas and possibly one spring (with the Caliente Option) are within the 0.4-kilometer (0.25-mile)-wide corridor, including its variations (Table 6-50). Although no formal delineations have been made, these areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. The corridor, including its potential variations, also crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary. DOE anticipates some changes to local drainage along the branch rail line and would design the rail line to accommodate existing drainage patterns.

As many as 14 springs and riparian areas occur outside the 400-meter (0.25-mile)-wide corridor and its variations, but within 5 kilometers (3 miles) of the corridor under the variations. Eight known populations of three sensitive animal species are associated with these aquatic resources. DOE anticipates that these populations would be unaffected and these areas would not be disturbed during construction or by the long-term presence of a railroad.

Soils in and adjacent to the corridor would be disturbed on approximately 12 square kilometers (3,000 acres) of land. The impacts of disturbing 12 square kilometers of soil along the 345-kilometer (214-mile)-long corridor would be transitory and small. However, several soil characteristics could influence construction activities and the amount of area disturbed. Soils susceptible to water or wind erosion occur along much of the corridor and its variations as do soils exhibiting relatively high shrink-swell characteristics (see Chapter 3, Section 3.2.2.1.4). Disturbance of erodible soils could lead to increased silt loads in water courses or increased soil transport by wind. Erosion control during construction and revegetation, or other means of soil stabilization after construction, would minimize these concerns. The presence of soils with poor (that is high) shrink-swell characteristics could influence the amount of area disturbed by construction if soils from outside areas had to be brought in for replacement or mixing with native soil.

As stated in Chapter 3, Section 3.2.2.1.4, variations identified for the Caliente-Chalk Mountain Corridor could avoid some biological resources, as listed in Table 6-53.

Table 6-53. Biological resources avoided by Caliente-Chalk Mountain Corridor variations.[a,b,c]

	Occurrence of resource			
	For unvaried segment of corridor		Occurrence avoided by variation	
Alignment variation resource	In corridor[b]	Within 5 km[c]	In corridor	Within 5 km
Caliente Variation				
Sensitive species–Needle Mountain Milkvetch	0	3	0	1
Springs or groups of springs	1	14	0	1
Crestline Variation				
Sensitive species–Needle Mountain Milkvetch	0	3	0	3
Springs or groups of springs	1	14	0	4
Mercury Highway, Topopah, Mine Mountain, and Area 4 Variations				
Sensitive species				
Beatley's scorpionweed	0	17	0	17
Funeral Mountain milkvetch	0	1	0	1
Largeflower suncup	1	18	1	17
Ripley's springparsley	1	1	1	0
Mine Mountain Variation only				
Sensitive species				
Largeflower suncup	0	1	0	1
Oasis Valley springsnail	0	1	0	1
Springs or groups of springs	1	14	0	1

a. Variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25 mile)], but avoided by the corridor variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the corridor variation.

6.3.2.2.3.4 Caliente-Chalk Mountain Rail Cultural Resources

Construction. The potential for cultural resource impacts in the Caliente-Chalk Mountain Corridor would be identical to that for the Caliente Corridor, as discussed in Section 6.3.2.2.1.4, until the Caliente-Chalk Mountain Corridor diverges at the northern boundary of the Nellis Air Force Range. From that point south the corridor passes through the Range and the Nevada Test Site to the repository site.

Archaeological site file searches have identified the presence of 100 recorded sites in the Caliente-Chalk Mountain Corridor (see Chapter 3, Section 3.2.2.1.5), including the variations (Appendix J, Section J.3.1.2). Of these, 34 are potentially eligible for inclusion in the *National Register of Historic Places.* Precise impacts to any of these resources cannot be specified until the rail alignment has been identified and its relationship to the known archaeological sites evaluated. At some point on the Nevada

Test Site, the Caliente-Chalk Mountain Corridor would intersect the 1849 Jayhawker's Emigrant Trail, but because physical expressions of the trail are unlikely, no direct impacts would occur. Although there are no known Native American resources in the corridor, there have been no field ethnographic studies. If DOE selected this corridor, this assessment of the potential for such impacts would have to wait until the completion of field studies involving Native Americans.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.3.5 Caliente-Chalk Mountain Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Caliente-Chalk Mountain branch rail line would be small (Table 6-54). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers and the public from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur in moving equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-55 lists these results.

Table 6-54. Impacts to workers from industrial hazards during rail construction and operations for the Caliente-Chalk Mountain Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	79	95
Lost workday cases	39	52
Fatalities	0.11	0.26
Noninvolved workers		
Total recordable cases	4.8	5.4
Lost workday cases	1.8	2.0
Fatalities	0.005	0.006
Totals[d]		
Total recordable cases	84	100
Lost workday cases	41	54
Fatalities	0.12	0.27

a. Totals for 43 months for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Caliente-Chalk Mountain rail corridor.

Table 6-56 lists the incident-free impacts, which include transportation along the corridor and along railways in Nevada leading to a Caliente-Chalk Mountain branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

6.3.2.2.3.6 Caliente-Chalk Mountain Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction and operation of a branch rail line in the Caliente-Chalk Mountain Corridor.

Table 6-55. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente-Chalk Mountain Corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	14,000,000	0.2	0.03
Commuting workers	61,000,000	0.6	0.08
Subtotals	*75,000,000*	*0.8*	*0.11*
Operations[c]			
Commuting workers	68,000,000	0.7	0.09
Totals	***140,000,000***	***1.5***	***0.2***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 43 months for construction.
c. Totals for 24 years for operations.

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Table 6-56. Health impacts from incident-free Nevada transportation for the Caliente-Chalk Mountain implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	700	740
Estimated latent cancer fatalities	0.02	0.28	0.3
Public			
Collective dose (person-rem)	7	12	18
Estimated latent cancer fatalities	0.003	0.01	0.01
Estimated vehicle emission-related fatalities	0.002	0.0055	0.0071

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

Construction. The length of the Caliente-Chalk Mountain Corridor, 345 kilometers (214 miles), would determine the number of workers required. The construction of a branch rail line in this corridor would require workers laboring for approximately 2 million hours or about 1,000 worker-years over a 43-month construction period. The route would require four construction camps to house workers temporarily (DIRS 154822-CRWMS M&O 1998, all).

Employment

Estimated employment in the region of influence attributable to the construction of a Caliente-Chalk Mountain branch rail line, would peak in 2007 at about 647 jobs. Clark County would supply approximately 569 of the workers and Nye County would supply about 22. These additional workers would represent an increase of less than 1 percent of the Clark and Nye County employment baselines. About 56 individuals would work in Lincoln County, adding about 2.3 percent to employment in the county. DOE anticipates changes in Lincoln County's employment would be primarily the result of indirect employment caused by the presence of transient construction workers. Employment of Caliente-Chalk Mountain Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth (2009 to 2010) of 15,240 jobs in the region of influence would be reduced by 612. The expected addition of 14,886 jobs in Clark County would be reduced by 594, and the expected growth of 330 jobs in Nye County would be reduced by 17. The expected growth of 24 jobs in Lincoln County would be reduced by 1. DOE anticipates that project-related workers not moving to Caliente-Chalk Mountain Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in the region of influence attributable to the construction of a Caliente-Chalk Mountain rail line would peak in 2009 at 589 persons. Clark County would gain about 527 residents, Nye County about 24, and Lincoln County about 38. The increase in population would be less than 1 percent of the baselines for Clark, Nye, and Lincoln Counties. Because the change in the population, relative to the population baselines, would be small and transient in Clark, Nye, and Lincoln Counties, impacts to housing or schools would be unlikely.

Economic Measures

The expected peak year changes in economic measures in the region of influence attributable to a branch rail line in the Caliente-Chalk Mountain Corridor would be increases of $18.6 million in real disposable income in 2009; $30.9 million in Gross Regional Product in 2007; and $2.1 million in State and local expenditures in the last year of construction, 2009. More than 93 percent of the real disposable income and Gross Regional Product would accrue to Clark County, which would experience about 78 percent of the additional spending by State and local governments. Lincoln County would gain slightly less than 4.6 percent of the change in real disposable income, 3.7 percent of the change in Gross Regional Product, and 16 percent of the expenditures by State and local governments. The increases in each economic measure would be less than 1 percent of the baseline in each affected county, except the increase of expenditures by State and local governments in Lincoln County would be 1.1 percent. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition and Operations Period. A period of slightly slower growth in employment in the region of influence would occur from 2010 to 2012. Following this period, employment to operate a Caliente-Chalk Mountain branch rail line would stimulate growth in the region. Growth in employment in the region of influence during the transitional period would average 19 fewer jobs than would occur without a Caliente rail line. Clark County would absorb the entire slower rate of growth, with an average of 82 fewer jobs. The Clark County employment baseline would average about 1 million during this period. Nye County would gain an average of 5 jobs and Lincoln County would gain 57 jobs during this period. The job gain in Lincoln County would represent a 2.2-percent average increase over the employment baseline in the 3-year period. The employment gain in Nye County would be less than 1 percent. A Caliente-Chalk Mountain rail line would contribute to the growth in residential population throughout the transition period and into the employment base after 2012.

Employment and Population

Estimated direct employment to operate a Caliente-Chalk Mountain rail line would be 47 jobs. Increased total employment in the region of influence would average about 78 jobs over the 24-year operations period (2010 to 2033). The majority, 57, would work in Lincoln County. The increases in Lincoln County employment attributable to a Caliente-Chalk Mountain branch rail line would be 2.1 percent of the baseline. On average, 14 jobs would be created in Clark County and 6 in Nye County. The change in the population in the region from the operation of a Caliente-Chalk Mountain branch line would average about 290 persons. DOE anticipates that 99 of these individuals would settle in Lincoln County, representing a 2.1-percent increase of the population baseline for the County. An additional 171 would live in metropolitan Clark County and represent less than 1 percent of the County's population baseline. The remaining individuals would live in Nye County and would affect the community by less than 1 percent. There would be no impacts to the school system or the housing market in Clark or Nye Counties. The increase in population in Lincoln County would add an average of about 22 students a year to the rolls of the school system. There would be no impact to housing in Lincoln County given the high housing vacancy rate in the County (see Chapter 3, Section 3.1.7.4).

Economic Measures

The estimated average, real disposable income increase attributable to the operation of a Caliente-Chalk Mountain branch rail line in the three-county region of influence would be $4.7 million per year. Contributions to real disposable personal income would range from $3.2 million in the early years of operation to $5.6 million in the last year. The annual increase in Gross Regional Product would average $4.6 million. On average, changes in real disposable income would exceed changes in Gross Regional Product. The increases in annual State and local government expenditures would average $1.6 million. The average impacts to real disposable income, Gross Regional Product, and State and local government expenditures from operating a Caliente-Chalk Mountain branch rail line would be less than 1 percent of the baselines for Clark and Nye Counties.

In Lincoln County, the changes in real disposable income and Gross Regional Product of operating a Caliente-Chalk Mountain branch rail line would range from about 1.7 percent for real disposable income to 2.6 percent for Gross Regional Product. State and local government spending would be higher by about 2.5 percent of the baseline. Workers associated with a Caliente-Chalk Mountain branch rail line would purchase many goods and services in the Lincoln County community. These dollars would continue to circulate largely within the area creating a positive economic impact. These impacts would not exceed historic short-term changes in the various socioeconomic measures.

DOE performed a detailed analysis was for the Caliente-Chalk Mountain Corridor. The results of this analysis, driven by the length of the Corridor, is representative of the potential variations (options and alternates) listed in Appendix J, Section J.3.1.2. The lengths of the variations are similar to those listed in Table 6-48.

In addition, DOE analyzed a sensitivity case that assumed all Lincoln County socioeconomic impacts would occur only in the City of Caliente. Under this assumption, City population would rise by 3 percent during construction and by 6.9 percent during operations. Employment would rise by about 5 percent during construction and about 7.2 percent during operations. If DOE selected this rail corridor, it would initiate additional engineering and environmental studies (including socioeconomic analyses); consult with Federal, State of Nevada, Native American, and local governments; and perform additional National Environmental Policy Act reviews as a basis for constructing and operating a Caliente-Chalk Mountain Corridor.

6.3.2.2.3.7 Caliente-Chalk Mountain Rail Noise and Vibration

Over most of its length, the Caliente-Chalk Mountain Corridor passes through undeveloped land managed by the Bureau of Land Management where human inhabitants are mostly isolated ranchers and persons involved with outdoor recreation. Almost half of the corridor’s length is on the Nellis Air Force Range and Nevada Test Site, where there is little potential for noise impacts. The Caliente and Caliente-Chalk Mountain Corridors are the same in most of Lincoln County and in the northeastern part of Nye County. The Towns of Caliente and Panaca are along the eastern end of the corridor. This corridor includes the Caliente Option, Eccles Option, and Crestline Option as starting points; these are fairly remote from any rural communities.

The five variations on restricted government land (see Appendix J, Section J.3.1.2), the White River Alternate, and the Garden Valley Alternate would not affect rural communities. The variations outside restricted government land pass through areas that are farmed. Hence, some rural residences in this area could fall within the region of influence for noise.

None of the communities along the Caliente-Chalk Mountain Corridor and its nine variations (see Appendix J, Section J.3.1.2), with the exception of Caliente, would be close enough to the rail line for noise impacts to approach the noise guidelines of 50 dBA for evenings and 60 dBA during the day (Table 6-57). The Caliente Option for connecting to the Union Pacific Railroad mainline would follow an old railroad bed through the center of the Town of Caliente. Noise levels in Caliente would not differ much from existing background noise levels associated with normal rail traffic through the community. Noise levels associated with waste shipments would occur at most three times a day and probably not in a given hour. Where a branch rail line passed through Caliente, train speed would be reduced for safety and noise levels would be minimized. Traffic could be delayed at one traffic crossing in the Town of Caliente. Adverse community response to the added rail noise would be unlikely because of the long-term presence of railroad traffic in Caliente, the short trains associated with the transport of waste shipments, and the low frequency of rail shipments to and from the site.

The estimated population residing within 2 kilometers (1.3 miles) of the Caliente-Chalk Mountain Corridor in 2035 would be about 28 persons.

Vibration. Except for the historic railroad station in Caliente, which is near the existing Union Pacific Railroad mainline, the branch rail line in the Caliente-Chalk Mountain Corridor and associated variations would be sufficiently distant from historic structures, cultural ruins, and buildings to preclude building damage as a result of ground vibration. Vibration levels at reduced train speeds would be unlikely to damage the Caliente Railroad station. Moreover, the vibrations added by the relatively few trains carrying waste to Yucca Mountain at slow speeds would not add appreciably to the total vibration to

Table 6-57. Estimated propagation of noise from the operation of a waste transport train with two locomotives in communities near the Caliente-Chalk Mountain Corridor.

Corridor[a]/community	Distance (kilometers)[b]	Noise (dBA)[c]
Caliente Option		
Caliente	0	>90 at 15 meters[d]
Panaca	6[e]	26.0
Crestline Option		
Panaca	4.5[e]	26.3
Eccles Option		
Caliente	6.5[e]	<26[f]
Rachel	>20[e]	<26

a. The White River, Garden Valley, Mercury Highway, Topopah, Mine Mountain, Area 4, and Orange Blossom Road variations occur on Nellis Air Force Range or Nevada Test Site lands, too far from any community to cause noise impacts.
b. To convert kilometers to miles, multiply by 0.62137.
c. Estimated values do no include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
d. 15 meters = 49 feet.
e. Noise estimates at distances greater than 2 kilometers (1.2 miles) have large uncertainty.
f. At these distances, the A-weighted sound pressure level is dominated by lower frequencies (less than 63 hertz) and would not be distinguishable from normal background levels of noise.

which the station is exposed from commercial trains that pass through Caliente. The small number of trips (three per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.3.8 Caliente-Chalk Mountain Rail Utilities, Energy, and Materials

Table 6-58 lists the use of fossil fuels and other materials in the construction of a Caliente-Chalk Mountain branch rail line.

Table 6-58. Construction utilities, energy, and materials for a Caliente-Chalk Mountain branch rail line.

Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)[c]
340 - 370	32 - 36	610 - 680	47 - 52	280 - 310

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.4 *Jean Corridor Implementing Alternative*

The Jean Corridor originates at the existing Union Pacific mainline railroad near Jean, Nevada. It travels northwest, passing near the Towns of Pahrump and Amargosa Valley before reaching the Yucca Mountain site. The Jean Corridor is about 181 kilometers (114 miles) long from its link at the Union Pacific line to the site. Variations of the route range from 181 to 204 kilometers (112 to 127 miles). Figure 6-18 shows this corridor along with possible variations identified by engineering studies (DIRS 154822-CRWMS M&O 1998 p. 1, Item 6; see Appendix J, Section J.3.1.2). The corridor variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-18. With the exception of differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the same among the possible corridor variations.

The construction of a branch rail line in the corridor would require approximately 43 months. Construction would take place simultaneously at a number of locations. An estimated two construction camps would be established at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities. A train would take about 4 hours to travel from the junction with the Union Pacific mainline to a Yucca Mountain

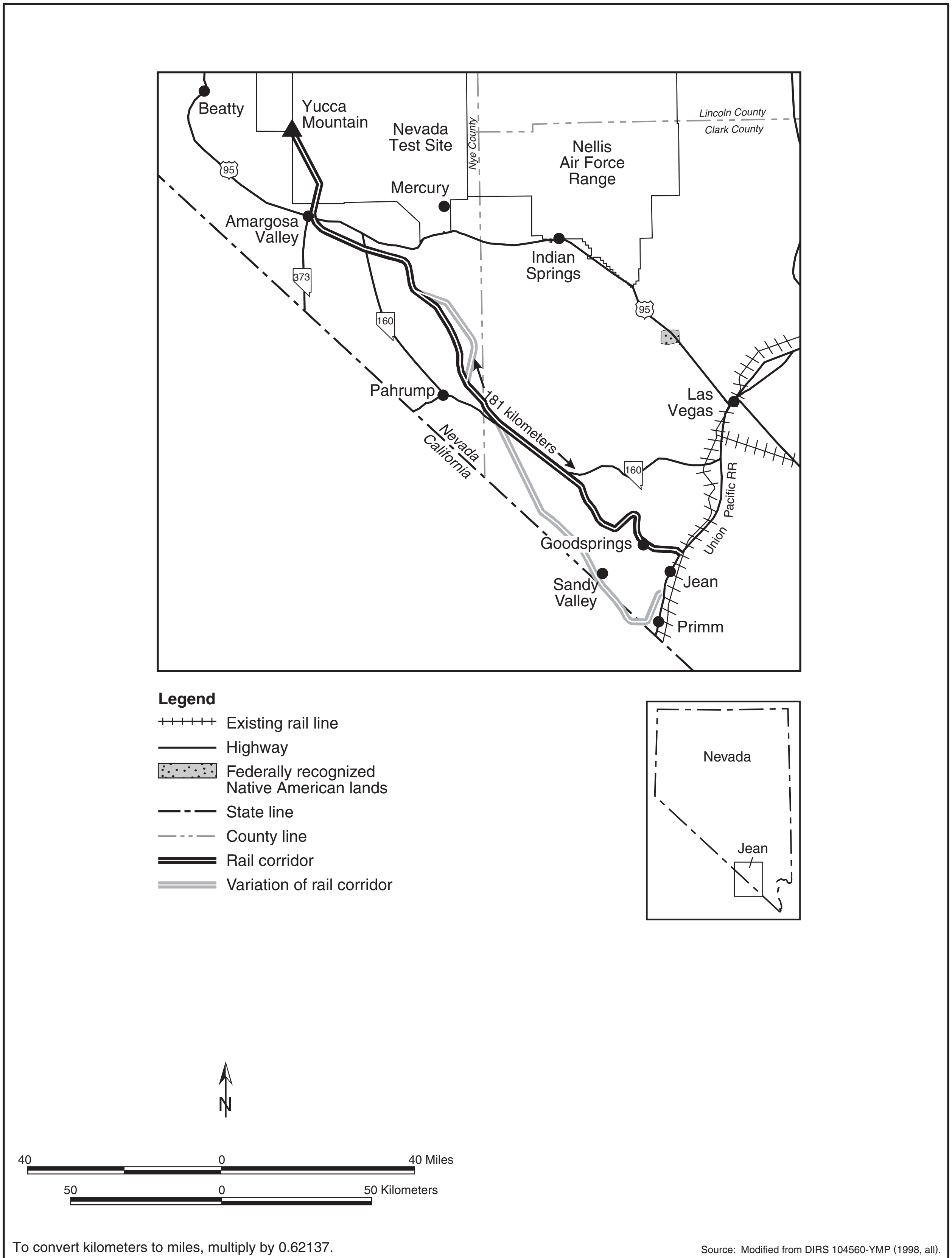

Figure 6-18. Jean Corridor.

Repository on a Jean branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Rail Operations Plan). The estimated life-cycle cost to construct and operate a branch rail line in the Jean Corridor would be $462 million in 2001 dollars.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology, including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; and utilities, energy, and materials. Impacts that would occur to air quality and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.4.1 Jean Rail Land Use and Ownership

Table 6-59 summarizes the amount of land required for the Jean Corridor, its ownership, and the estimated amount of land that would be disturbed, as well as ranges for the variations. Table 6-60 summarizes the amount of land required for the Jean Corridor variations and its ownership.

Table 6-59. Land use in the Jean Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	181	181 - 204
Land area in 400-meter[c]-wide corridor (square kilometers)[d]	72 (100)	72 - 82
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	60 (83)	60 - 69
Air Force	None	None
DOE	8.5 (12)	8.5 - 8.5
Private	3.5 (5)	0.1 - 3.5
Other	None	None
Land area in 60-meter[e] right-of-way (square kilometers)	10.9	10.8 - 12.2
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	6.6	6.6 - 7.4
Outside 60-meter right-of-way	2.6	2.6 - 2.9

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. 60 meters = 200 feet.

Table 6-60. Variations in the Jean Corridor.[a]

Variation	Length (kilometers)[b]	Area in variation (square kilometers)[c]	Land ownership [square kilometers (percent)]	
			Bureau of Land Management	Private
Wilson Pass Option	73.5	29.4	29.4 (99.98)	0.01 (0.02)
Pahrump Valley Alternate	32.1	12.8	12.7 (99.2)	0.1 (0.8)
Stateline Pass Option	91.9	36.8	36.79 (99.97)	0.01 (0.03)

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.

Construction. The Jean Corridor (Wilson Pass Option) crosses eight Bureau of Land Management grazing allotments (Mount Stirling, Spring Mountain, Stump Springs, Table Mountain, Wheeler Wash, and three unnamed and unallotted areas); two wild horse and burro herd management areas (both in Pahrump Valley); the Old Spanish Trail/Mormon Road special recreation management area; and four areas designated as available for sale or transfer. It also crosses several telephone, pipeline, highway, and power line rights-of-way. The corridor is within 1.6 kilometers (1 mile) of the Toiyabe National Forest and three mines (Bluejay, Snowstorm, and Pilgram). The Wilson Pass Option also passes through Bureau of Land Management Class II lands in the vicinity of Wilson Pass in the Spring Mountains, potentially affecting the recreational use of this area.

The Stateline Pass Option origination location along an existing Union Pacific rail line conflicts directly with lands set aside for the proposed Ivanpah Valley Airport under the Ivanpah Valley Airport Public Lands Transfer Act (Public Law 106-362, 114 Stat. 1404). The Stateline Pass Option crosses the California-Nevada boundary line along Bureau of Land Management lands and passes near the Stateline Wilderness Area established by the California Desert Conservation Act. Construction activities could affect recreational use of the Stateline Wilderness Area. Impacts would be similar to the construction impacts discussed in Section 6.3.2.1. Corridor variations are listed in Appendix J, Section J.3.1.2. Impacts common to the rail implementing alternates are discussed in Section 6.3.2.1. The following paragraphs discuss impacts unique to this corridor.

The transfer of land from Bureau of Land Management for the Ivanpah Valley Airport would require DOE to realign the Stateline Pass Option for constructing a branch rail line.

Construction activities could affect the Old Spanish Trail/Mormon Road special recreation management area. Ease of access from one portion of the management area to the other would be reduced. These impacts could be mitigated by providing access to connect the parcels separated by the railroad right-of-way.

In the vicinity of Pahrump, Nevada, a branch rail line in the Jean Corridor would pass through approximately 9 kilometers (5.5 miles) of private property. As discussed in Section 6.3.2.1, DOE would have to make arrangements with owners to use this land. As indicated in Appendix J, Section J.3.1.2, the North Pahrump Alternate includes no private property. The North Pahrump Alternate would abut a Bureau of Land Management utility corridor and a section of the Toiyabe National Forest and could affect access to these recreational areas.

During the construction and operation and monitoring phases of the Proposed Action, there would be a potential for encroachment of the Jean Corridor by private interests. If encroachment occurred, conflicts could result as impediments to the full use of the land. Areas most likely for use by private interests are those already privately owned in the vicinity of Pahrump and those that are currently designated for sale or transfer by the Bureau of Land Management.

If DOE decided to build and operate a branch rail line in the Jean corridor, it would consult with the Bureau of Land Management and other affected agencies and with Native American tribal governments to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a right-of-way.

Although there are no known community development plans that would conflict with the rail line, the presence of a rail line could influence future development and land use along the railroad in the communities of Amargosa Valley, Goodsprings, Jean, Johnnie, and Pahrump (that is, zoning and land use might differ depending on the presence or absence of a railroad). Construction of a branch rail line within the Jean corridor would require conversion of land within wild horse or wild horse and burro management areas; however, because the railroad would be unlikely to interfere with animal movements, the functionality of these areas would not be affected.

Operations. As with the other corridors, DOE expects the operation of a branch rail line in the corridor to cause fewer impacts than construction. Impacts due to rail operations would be similar to those described in Section 6.3.2.1.

6.3.2.2.4.2 Jean Rail Hydrology

Surface Water

Chapter 3, Section 3.2.2.1.3, notes that there are no surface-water resources along the Jean Corridor, including its variations.

Table 6-61 lists flood zones identified along the Jean Corridor and its variations. The Federal Emergency Management Agency maps from which DOE derived the flood zone information provided coverage for 90 percent of the corridor length. This corridor would cross seven 100-year flood zones or flood-zone groups before entering the Nevada Test Site. One of the two variations would increase the number of flood zones crossed by 1; the other segment would have no change. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Table 6-61. 100-year flood zones crossed by the Jean Corridor and its variations.[a,b]

Corridor portion	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (Yes or No)
Jean to Yucca Mountain	0.6	Three tributaries leading to Roach Lake (intermittent)	Y-2
	0.7	Lovell Wash with drainage (intermittent)	Y-2
	0.4	Two unnamed washes northwest of Lovell Wash	N
	4.1	Peak Springs Alluvial Fan (dry)	N
	1.9	Wheeler Wash (dry)	N
	0.3	Wash drainage leading to Alkali Flats (dry)	N
	0.1	Rock Valley Wash (intermittent)	N
Variations			
1. Pahrump Valley Alternate	None	Located northeast of corridor.	
2. Stateline Pass Option	0.4	Crosses two tributaries to Roach Lake (dry).	
	0.8	Crosses Potasi Wash, an unnamed wash, and Lovell Wash drainage.	
	1.1	Crosses four unnamed washes and Peak Springs Fan (intermittent).	

a. Areas where natural floodwater movement could be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Clark and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).

b. About 10 percent of the Jean Corridor is not available on Federal Emergency Management Agency maps because a portion of the route is on the Nevada Test Site.

c. To convert kilometers to miles, multiply by 0.62137.

d. Certain 100-year flood zones can be avoided by alternative corridor segments. These are identified with a “Y” (yes) and a number representing the variation(s) that avoid the specific flood zone. The same flood zone might be crossed by both the corridor and variations at different locations. In such cases, the feature will be marked “Avoided” for the corridor route, but will appear again for the variation.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3, Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Jean Corridor passes).

The estimated amount of water needed for construction of a rail line in the corridor for soil compaction, dust control, and workforce use would be about 500,000 cubic meters (410 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 23 wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 22,000 cubic meters (18 acre-feet). Most (89 percent) of the water would be used for compaction of fill material. The estimate of fill quantities needed for construction would vary if DOE used a variation. Use of the Pahrump Valley Alternate or Stateline Pass Option would involve an increase in fill material (over that required for the corridor) and would increase the total water demand by 12 or 27 percent, respectively.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-62 summarizes the status of the hydrographic areas associated with the Jean Corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins. The use of variations would change the number of hydrographic areas crossed, but would have no effect on the portion of the corridor crossing Designated Groundwater Basins.

Table 6-62. Hydrographic areas along the Jean Corridor and its variations.

Description	Hydrographic areas	Designated Groundwater Basins	
		Number	Percent of corridor length
Jean Corridor	7	5	90
With Stateline Pass Option	6	4	90
With Pahrump Valley Alternate	7	5	90

The withdrawal of 22,000 cubic meters (18 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 23 wells along the corridor would mean that several of the hydrographic areas would have multiple wells. As indicated in Table 6-62, about 90 percent of the corridor length is over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater basins. With such a large portion of the corridor over these basins, however, this would mean trucking water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources are not adversely affected.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Jean corridor would require about 27,000 tanker-truck loads of water or about 14 truckloads each day for each work camp area along the corridor. Again, water obtained from permitted sources, which would provide water within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

6.3.2.2.4.3 Jean Rail Biological Resources and Soils

Construction. The construction of a branch rail line in the Jean Corridor would disturb approximately 9.3 square kilometers (2,300 acres) of land (Table 6-59). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. Table 6-63 compares the approximate area of disturbance in each land-cover type along all variations of the Jean Corridor to the area in each land-cover type in Nevada. In addition, the table lists the percentage of the area that would be disturbed. The fraction disturbed for each cover type would be very small. The disturbance would not have a discernible impact on any land-cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to that in the unvaried corridor.

Table 6-63. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Jean Corridor.[b,c]

Land-cover type	Wilson Pass Option		Stateline Pass Option		Area in Nevada	Percent disturbed
	Percent of corridor length	Land area	Percent of corridor length	Land area		
Agriculture	0	0	0	0	5,200	0
Blackbrush	18.4	1.69	0.1	0.01	9,900	0.017
Creosote-bursage	58.6	5.39	80.8	8.32	15,000	0.055
Grassland	0	0	0	0	2,800	0
Greasewood	0	0	0	0	9,500	0
Hopsage	0	0	0	0	630	0
Juniper	0	0	0	0	1,400	0
Mojave mixed scrub	21.1	1.94	14.6	1.5	5,600	0.035
Pinyon-juniper	0	0	0	0	15,000	0
Playa	0	0	0	0	7,000	0
Sagebrush	0	0	0	0	67,000	0
Sagebrush/grassland	0	0	0	0	52,000	0
Salt desert scrub	2	0.18	1.8	0.19	58,000	<0.001
Urban	ND[d]	ND	ND	ND	2,400	ND
Total[e]	100	9.2	97.3[f]	10	250,000	N/A[g]

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.
e. Totals might differ from sums of values due to rounding.
f. About 2.7 percent of land would be in California for the proposed Jean corridor with the Stateline Pass Option.
g. N/A = not applicable.

The Jean Corridor, including its variations passes through desert tortoise habitat along its entire length, so construction activities would disturb approximately 9.3 square kilometers (2,300 acres) of desert tortoise habitat, some of which is designated as critical habitat. Construction activities could kill individual desert tortoises, and the presence of a rail line could disrupt movements of individuals. The abundance of tortoises is low along much of this corridor; however, some areas in the Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have higher abundance (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). DOE anticipates that losses would be few and would be unlikely to affect the regional population of the desert tortoise. Relocation of tortoises along the corridor prior to construction would minimize losses of individuals. DOE would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) in relation to this species if it selected this corridor and would implement all terms and conditions required by the Fish and Wildlife Service.

Two populations of Pinto beardtongue (a Bureau of Land Management sensitive species) occur in the corridor and could be affected directly or indirectly by land-clearing activities. The locations of these populations would be identified though surveys prior to disturbance and would be avoided to the extent possible. No populations of sensitive species occur in the Stateline Pass Option.

There are 33 populations of seven sensitive plant species outside the 400-meter (0.25-mile)-wide corridor, but within 5 kilometers (3 miles) of the corridor. Thirteen populations of five sensitive plant species are outside the corridor but within 5 kilometers of the Stateline Pass Option. These populations would not be affected because land disturbance would not extend to these areas. Changes in the aquatic or soil environment in these areas as a result of construction would be unlikely.

Ten designated game habitat areas for bighorn sheep, mule deer, or quail occur within the corridor and 16 areas occur within 5 kilometers (3 miles) of the corridor. The Stateline Pass Option avoids five of the designated game habitat areas in the corridor.

The Wilson Pass Option crosses three Herd Management Areas for wild horses and burros (DIRS 104593-CRWMS M&O 1999, p. 3-29). The Stateline Pass Option would avoid two of these areas. Construction activities in these areas would result in the loss of a small amount of habitat and probably would disturb animals or their movements for the duration of the activities.

No springs, perennial streams, or riparian areas occur in the Jean Corridor. Eleven springs or groups of springs are outside the corridor, but within 5 kilometers (3 miles) of the corridor. Impacts to biological resources associated with these areas are not anticipated. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States, although formal delineations have not been made (DIRS 104593-CRWMS M&O 1999, p. 3-29). DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary. The Department anticipates some changes to local drainage along the potential branch rail line and would design the rail line to accommodate existing drainage patterns.

Soils in and adjacent to the corridor would be disturbed on approximately 9.3 square kilometers (2,300 acres) of land during construction of a railroad. Impacts to soils in the corridor, including its variations [6.5 square kilometers (1,600 acres)], would be small, but could occur throughout construction. However, several soil characteristics could influence construction activities and the amount of area disturbed. Soils susceptible to wind erosion occur along much of the corridor and its variations (see Chapter 3, Section 3.2.2.1.4.). Soils considered to be highly susceptible to water erosion and having poor stability characteristics are also present, but along much smaller portions of the corridor. Disturbance of erodible soils could lead to increased silt loads in water courses or increased soil transport by wind. Erosion control during construction and revegetation, or other means of soil stabilization after construction, would minimize these concerns. The presence of soils with poor (that is, high) shrink-swell and stability characteristics could influence the amount of area disturbed by construction if soils from outside areas had to be brought in for replacement or mixing with native soil. The source of suitable fill material and the land area that would be disturbed in obtaining the material is presently unknown, so the potential for impacts to soils and biological resources associated with the borrow areas cannot be determined.

Soils classified as unstable fill also occur along portions of the Jean corridor, including its variations. The amount of land disturbance in the corridor for stabilization of a rail line and outside the corridor at the source of fill material could increase due to the presence of these soils. The source of suitable fill material and the land area that would be disturbed in obtaining the material is unknown at present, so DOE cannot determine the potential for impacts to soils and biological resources associated with the borrow areas.

As stated in Chapter 3, Section 3.2.2.1.4, variations identified for the Jean Corridor could avoid some biological resources, as listed in Table 6-64.

6.3.2.2.4.4 Jean Rail Cultural Resources

Construction. The Jean Corridor passes through the Goodsprings and Johnnie historic mining districts, and intersects the historic Yellow Pine Mining Company Railroad grade. In the southern part of the Pahrump Valley, the corridor, including the Wilson Pass and Stateline Options, crosses the Old Spanish Trail, which is under consideration for designation as a National Historic Trail. Based on Bureau of Land Management resource planning, both the Goodsprings and Pahrump Valleys are expected to contain fairly high numbers of potentially significant archaeological and historic sites. Precise impacts from rail line construction activities would be identified after completion of a cultural resource study of the corridor.

Table 6-64. Biological resources avoided by Jean Corridor variations.[a]

Alignment variation resource	Occurrence of resource: For unvaried segment of corridor – In corridor[b]	Within 5 km[c]	Occurrence avoided by variation – In corridor	Within 5 km
Stateline Pass Variation				
Sensitive species				
Allen's big-eared bat	0	1	0	1
Desert bearpoppy	0	3	0	1
Fringed myotis	0	1	0	1
Gila monster	0	1	0	1
Long-legged myotis	0	1	0	1
Pinto beardtongue	2	18	2	17
Sheep fleabane	0	1	0	1
Spring Mountain milkvetch	0	2	0	2
Townsend's big-eared bat	0	1	0	1
White-margined beardtongue	0	5	0	3
Yuma myotis	0	1	0	1
Game habitat				
Bighorn sheep–crucial	1	1	1	1
Bighorn sheep–migration corridor	2	0	1	0
Bighorn sheep-winter	1	7	0	3
Chukar–crucial	1	0	1	0
Mule deer–summer crucial	0	2	0	1
Mule deer–winter	2	2	1	1
Quail–crucial	3	4	1	3
Springs or groups of springs	0	11	0	5
Herd Management Units	3	0	2	0

a. Variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25 mile)], but avoided by the corridor variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the corridor variation.

Archaeological site file searches for the Jean Corridor and its variations (Appendix J, Section J.3.1.2) revealed six recorded archaeological sites, four of which have been evaluated as being not eligible for the *National Register of Historic Places.*

There are no known Native American resources in this corridor, although the corridor passes through the traditional homelands of the Pahrump Paiute Band. In the early historic period, there were several village sites in the northern area at the base of the Spring Mountains; a branch rail line could affect some of these locations. Pending completion of field ethnographic studies, there could be other sites or resources of importance to Native Americans along this corridor that rail construction activities could affect.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.4.5 Jean Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Jean branch rail line would be small (Table 6-65). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-66 lists these results.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in using the Jean Corridor. Table 6-67 lists the incident-free

Table 6-65. Impacts to workers from industrial hazards during rail construction and operations for the Jean Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	67	73
Lost workday cases	33	40
Fatalities	0.09	0.20
Noninvolved workers		
Total recordable cases	4.0	4.1
Lost workday cases	1.5	1.5
Fatalities	0.004	0.004
Totals		
Total recordable cases	71	77
Lost workday cases	35	41
Fatalities	0.10	0.20

a. Totals for 43 months for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.

impacts, which include transportation along the corridor and along railways in Nevada leading to a Jean branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that would not have the capability to load rail casks while operational.

6.3.2.2.4.6 Jean Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction and operation of a branch rail line in the Jean Corridor.

Construction. The length of the Jean Corridor, 181 kilometers (112 miles), is the principal factor that would determine the number of workers required to construct a branch rail line. The construction of a branch rail line in this corridor would require workers laboring approximately 1.7 million hours or 855 worker years over a 43-month construction period. The workers would be temporarily housed in two construction camps (DIRS 154822-CRWMS M&O 1998, all).

Table 6-66. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Jean Corridor.

Jean	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Materials delivery vehicles	10,000,000	0.2	0.02
Commuting workers	52,000,000	0.5	0.07
Subtotals	*62,000,000*	*0.7*	*0.09*
Operations[c]			
Commuting workers	52,000,000	0.5	0.07
Totals	***110,000,000***	***1.2***	***0.16***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 43 months for construction.
c. Totals for 24 years for operations.

Table 6-67. Health impacts from incident-free Nevada transportation for the Jean Corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	720	760
Estimated latent cancer fatalities	0.02	0.29	0.3
Public			
Collective dose (person-rem)	7	150	160
Estimated latent cancer fatalities	0.003	0.08	0.08
Estimated vehicle emission-related fatalities	0.002	0.08	0.08

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

Employment

DOE anticipates that the total (direct and indirect) employment in the region of influence attributable to rail line construction would peak in 2007 at about 526 jobs. DOE anticipates that 92 percent or 483 workers, would come from Clark County. Approximately 42 workers would come from Nye County and 1 from Lincoln County. The increase in employment represents less than 1 percent of the baseline for Clark, Nye, and Lincoln Counties. Employment of Jean Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth (2009 to 2010) of 15,240 jobs in the region of influence would be reduced by 490. The expected addition of 14,886 jobs in Clark County would be reduced by 449, and the expected growth of 330 jobs in Nye County would be reduced by 41. The expected growth of 24 jobs in Lincoln County would be unaffected. DOE anticipates that project-related workers not moving to Jean Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in the region of influence attributable to the construction of a Jean branch rail line, which would lag behind increases in employment, would peak in 2009 at about 492 persons. DOE anticipates that approximately 449 would live in Clark County, 42 in Nye County, and 1 in Lincoln County. The increase in population would be less than 1 percent of each county's population baseline. Because the impacts to population in each county would be small and transient, impacts to schools or housing would be unlikely.

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The expected peak changes in the region of influence attributable to constructing a branch rail line in the Jean Corridor would be increases of about $15.2 million in real disposable income in 2009; about $25.7 million in Gross Regional Product in 2007; and about $1.6 million in State and local expenditures in 2009. More than 96 percent of the increases in real disposable income and Gross Regional Product and about 91 percent of the increase in State and local government expenditures would occur in Clark County. Most of the remainder of the increase would occur in Nye County. The impacts to Clark, Nye, and Lincoln Counties for each of these measures would be less than 1 percent for each county's applicable baseline. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition and Operations Period. A period of slightly slower employment growth would occur from 2010 to 2012, and then employment to operate a branch rail line would contribute to an increased rate of growth. Growth in employment in the region of influence during this transitional period would be approximately 15 fewer jobs annually than would occur without a rail line in the Jean Corridor. Clark County would experience all of the slower rate of growth. During this period, the Clark County employment baseline would be about 1 million jobs. Nye County would gain 1 job during this period. The Jean rail line would contribute to the growth in residential population throughout the transition period.

Employment and Population

Estimated direct employment for the operation of a branch rail line in the Jean Corridor would be 36 workers. The total increase in employment in the region of influence would average 54 jobs over the 24-year operation period (2010 to 2033). On average, 52 of these jobs would be in Clark County, 1 in Nye County, and none in Lincoln County. These increases represent less than 1 percent of the counties' employment baselines. An increase in the Clark and Nye County populations attributable to a Jean rail line would be about 208 individuals, 91 percent of whom would live in Clark County. The balance would live in Nye County. The impact to the baseline population in both counties would be less than 1 percent. Because the increase to the population baseline would be small, impacts to the school system or housing would be unlikely. There would be no change in employment or the number of residents in Lincoln County due to a Jean rail line.

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Economic Measures

In the three-county region of influence the greatest increase in real disposable income above the baseline attributable to operations would occur in 2033, the last year of operation. This increase would be $4.3 million; the average increase in each of the 24 years of operation would be about $3.7 million. The increase in Gross Regional Product would average about $3.6 million. On average during rail line operations, changes in real disposable income would exceed changes in Gross Regional Product. Annual State and local government expenditures would average $722,000. Nearly all of the economic activity would occur in Clark County; virtually none would occur in Lincoln and Nye Counties. Annual impacts to real disposable income, Gross Regional Product, and State and local government expenditures from the operation of a branch rail line in the Jean Corridor would be less than 1 percent of the baseline for each county.

The results of the detailed analysis performed for the Jean Corridor driven by the corridor length are representative of the variations (options and alternates) listed in Appendix J, Section J.3.1.2. The lengths of the variations are similar to those listed in Table 6-60.

6.3.2.2.4.7 Jean Rail Noise and Vibration

The Wilson Pass and Stateline Pass Options in the southern portion of the Jean Corridor and the Pahrump Valley Alternate pass through mostly U.S. Government land set aside for use by DOE or managed by the Bureau of Land Management. They also cross a small amount of private land. The Wilson Pass Option passes the communities of Amargosa Valley, Goodsprings, Jean, and Pahrump. In addition, the Stateline Pass Option passes the small communities of Sandy Valley and Primm. The smaller rural communities associated with the Jean Corridor and its variations (Appendix J, Section J.3.1.2) would be likely to experience noise levels from the operation of trains in excess of the benchmark nighttime noise level of 50 dBA, but not the daytime residential noise level of 60 dBA (Table 6-68). Jean and Primm are principally commercial business communities consisting of gaming industry, retail, and Primm businesses. In addition, the potential for growth and development in the Jean and Pahrump areas could place residents and businesses close to a Jean branch rail line, leading to noise impacts from both construction and operations.

Table 6-68. Estimated propagation of noise (dBA) from the operation of a waste transport train with two locomotives in communities near the Jean Corridor.

Corridor/community	Distance (kilometers)[a]	Noise (dBA)[b]
Wilson Pass Option		
Jean	1.6	48
Goodsprings	1.2	54
Pahrump	2.0	43
Amargosa Valley	1.0	57
Stateline Pass Option		
Stateline	1.6	48
Sandy Valley	1.0	57
Goodsprings	1.2	54
Pahrump	2.0[c]	43
Amargosa Valley	1.0	57

a. To convert kilometers to miles, multiply by 0.62137.
b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (33 feet) from the tracks.
c. Noise estimates at distances greater than 2 kilometers (1.2 miles) have large uncertainty.

Noise impacts for the Jean Corridor would be limited because, at distances more than 0.8 kilometer (0.5 mile) daytime noise from trains would be below noise standards for residential areas (60 dBA) and because few residents and businesses are this close to the corridor. Nonetheless, because a Jean branch rail line could pass near some communities, there would be a potential for noise impacts from both construction and operations. As discussed in Section 6.3.2.1, in areas where a branch rail line or variation passed near a community, transports could be limited to the extent necessary to ensure that noise was below levels listed as accepted noise hazards.

The estimated population that would reside within 2 kilometers (1.3 miles) of the Jean Corridor in 2035 is about 1,300 persons.

Vibration. The Jean Corridor and its variations would be distant [more than 200 meters (660 feet)] from historic structures and buildings. There are no known ruins of cultural significance along the corridor. Therefore, vibration impacts to structures would be unlikely. The small number of trips (three per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.4.8 Jean Rail Aesthetics

The Wilson Pass Option of the Jean Corridor would pass through Class II lands in the Goodsprings Valley and Spring Mountains. The objective of Bureau of Land Management Visual Resource Class II lands is to preserve the existing character of the landscape. According to the Bureau, the level of changes to the landscape should be low. Management activities could be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture of the characteristic landscape. Because of this, the building of a rail line in the Wilson Pass Option probably would require more stringent construction practices to limit visual resource impacts. Although impacts due to construction activities would be short term, visual impacts to recreational land use in this area would be likely. If DOE selected this option, additional consultation with the Bureau would be necessary to address aesthetic impacts.

The operation of a branch rail line through the Class II visual resource lands in the vicinity of Wilson Pass in the Spring Mountains would draw attention to the rail line and degrade the aesthetics of the area, thereby reducing the quality of recreational use of the area.

6.3.2.2.4.9 Jean Rail Utilities, Energy, and Materials

Table 6-69 lists the use of fossil fuels and other materials in the construction of a Jean branch rail line.

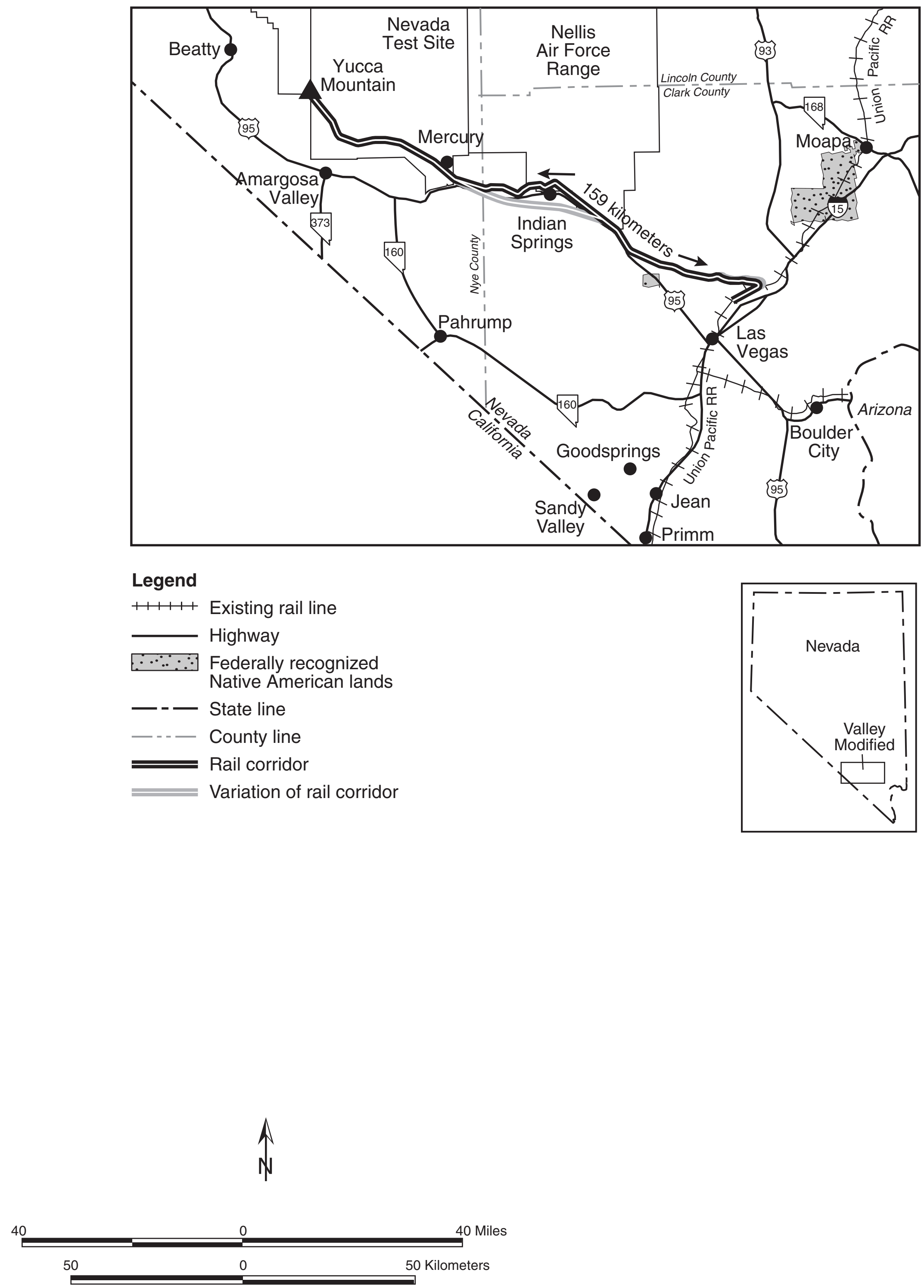
Table 6-69. Construction utilities, energy, and materials for a Jean branch rail line.

Route	Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
Jean	180 - 200	26 - 30	500 - 570	26 - 29	150 - 170

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.5 *Valley Modified Corridor Implementing Alternative*

The Valley Modified Corridor originates near the existing Apex rail siding off the Union Pacific mainline railroad. It travels northwest passing north of the City of Las Vegas, north of the Town of Indian Springs, parallel to U.S. 95 before entering the southwest corner of the Nevada Test Site and reaching the Yucca Mountain site. The Valley Modified Corridor is about 159 kilometers (98 miles) long from its link with the Union Pacific line to the site. Variations of the route range from 157 to 163 kilometers (98 to 101 miles). Figure 6-19 shows this corridor along with possible variations identified by engineering studies (DIRS 154960-CRWMS M&O 1998, all). The variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-19. With the exception of differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the



To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104560-YMP (1998, all).

Figure 6-19. Valley Modified Corridor.

same among the possible variations. The Indian Hills Alternate of the Valley Modified Corridor also crosses the original route of the historic Las Vegas-to-Bullfrog Stage Road.

The construction of a branch rail line in the corridor would require approximately 40 months. Construction would take place simultaneously at a number of locations along the corridor. Two construction camps would be established to provide temporary living accommodations for construction workers and construction support facilities. A train would take about 3 hours to travel from the junction with the Union Pacific mainline to the Yucca Mountain Repository on a Valley Modified branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Rail Operations Plan). The estimated life-cycle cost to construct and operate a branch rail line in the Valley Modified Corridor would be $283 million in 2001 dollars.

The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to aesthetics, and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.5.1 Valley Modified Rail Land Use and Ownership

Table 6-70 summarizes the amount of land required for the Valley Modified corridor, its ownership, and the estimated amount of land that would be disturbed, as well as ranges for the variations. Table 6-71 summarizes the amount of land required for the variations of the Valley Modified Corridor and its ownership.

Table 6-70. Land use in the Valley Modified Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	159	157 - 163
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	63 (100)	63 - 65
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	34 (53)[e]	29.9 - 36.7
Air Force	7 (11)	3.6 - 7.5
DOE	21 (32)	20. 6 - 20.6
Private	0.2 (0.3)	0 - 0.18
Fish and Wildlife Service	1.8 (3)	1.7 - 4.1
Land area in 60-meter[f] *right-of-way (square kilometers)*	9.6	9.4 - 9.8
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	4.4	4.3 - 4.5
Outside 60-meter right-of-way	0.6	0.68 - 0.7

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. Percentages do not total 100 due to rounding.
f. 60 meters = 200 feet.

Construction. The corridor crosses three Bureau of Land Management grazing allotments (Wheeler Slope, Indian Springs, and Las Vegas Valley), two wilderness study areas (Nellis ABC and Quail Spring, both recommended by the Bureau as unsuitable for inclusion in the National Wilderness System), and one area designated as available for sale or transfer (DIRS 104993-CRWMS M&O 1999, Table 7, p. 22). It also crosses several telephone, pipeline, highway, and power line rights-of-way, and the Nellis Air Force Base small arms range. Impacts common to rail implementing alternates are discussed in Section 6.3.2.1. The following paragraphs discuss impacts unique to this corridor.

Table 6-71. Variations in the Valley Modified Corridor.[a]

Variation	Length (kilometers)[b]	Land area in variation (square kilometers)[c]	Land ownership [square kilometers (percent)] Bureau of Land Management	Fish and Wildlife Service	Department of Defense	Private
Indian Hills Alternate	45.2	18.1	18.1 (100)	--[d]	--	--
Sheep Mountain Alternate	23.3	9.8	3.2 (33)	3.4 (35)	3.1 (32)	--
Valley Connection	21.1	2.7	2.5 (93)	--	0.01 (0.4)	0.2 (6.6)

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.
d. -- = none.

Variations to this corridor are listed in Appendix J, Section J.3.1.2. The Indian Hills Alternate would avoid Nellis Air Force Range by traveling south of Indian Springs. This variation would cross Fish and Wildlife Service lands and pass almost entirely within a Bureau of Land Management utility corridor. It would also pass through a Bureau Land Withdrawal Area (N50945) for a power project. The Sheep Mountain Alternate would pass through the Nellis Small Arms Range and Nellis Wilderness Study Areas A, B, and C, as well as the Quail Mountain Wilderness Study Area and the Desert National Wildlife Range. Although the Bureau considers these Wilderness Study Areas unsuitable for inclusion in the National Wilderness System, DOE would have to consult with the Bureau before it could build a branch rail line.

The corridor passes along the Las Vegas metropolitan area's northern boundary, in an area that is currently undergoing growth and where future commercial and residential growth might occur. However, metropolitan area growth might not extend to the corridor area until after the operations phase of the repository, when DOE assumes that it would no longer have use for a branch rail line. The corridor also passes next to the Dry Lake siding and within about 1.6 kilometers (1 mile) of the Las Vegas Paiute Indian Reservation north of Las Vegas. There would be no significant land-use impact to this reservation because of its distance from the corridor.

During the construction and operation and monitoring phases of the Proposed Action, there would be a potential for encroachment of the Valley Modified Corridor by private interests. If encroachment occurred, conflicts could result as impediments to the full use of lands. Areas most likely for use by private interests are those currently designated for sale or transfer by the Bureau of Land Management.

Two segments of the corridor encroach slightly on the Nellis Air Force Range. The U.S. Air Force has noted the potential for safety risks of crossing lands that are hazard areas and encompass weapons safety footprints for live weapons deployment. DOE has identified the Indian Hills Alternate, which would avoid the larger encroachment (see Appendix J, Section J.3.1.2). If DOE decided to build and operate a branch rail line in the Valley Modified corridor, it would consult with the Bureau of Land Management, U.S. Air Force, other affected agencies and Native American Tribal governments, and other DOE program operations on the Nevada Test Site to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a rail line right-of-way. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65; 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through any part of the Range.

Although there are no known community development plans that would conflict with the rail line, the presence of a rail line could influence future development and land use along the railroad in the communities of Indian Springs and North Las Vegas (that is, zoning and land use might differ depending on the presence or absence of a railroad).

Operations. DOE anticipates that operations along the Valley Modified Corridor would cause fewer impacts than construction. Operations impacts would be similar to those discussed in Section 6.3.2.1.

6.3.2.2.5.2 Valley Modified Rail Air Quality

Construction. The Valley Modified Corridor and some of its variations would involve construction in the Las Vegas Valley air basin, which is in nonattainment for particulate matter (PM_{10}) and carbon monoxide (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54). To assess nonradiological air quality impacts from branch rail line construction in this air basin, DOE compared emissions from earthmoving activities and vehicles to General Conformity and Prevention of Significant Deterioration thresholds. Appendix G, Section G.1.4.1, describes the method used to determine PM_{10} emissions from earthmoving activities. This method takes no credit for dust suppression measures; however, the analysis for transportation construction activities included dust suppression measures. Appendix G, Section G.1.4.5 describes the method used to determine criteria pollutant emissions from construction vehicle activity which, for the Valley Modified Corridor, would consume an estimated 7.1 million liters (about 1.9 million gallons) of diesel fuel and 150,000 liters (38,000 gallons) of gasoline in the nonattainment area over the length of the construction period.

Eighty-four kilometers (52 miles) of the total 160 kilometers (98 miles) of a branch rail line in the Valley Modified Corridor would be in the nonattainment area. Table 6-72 lists emission rates of PM_{10} and carbon monoxide from earthmoving activities and vehicle emissions in the nonattainment area assuming a work crew completed this section over 21 months and used standard construction techniques. There would be five borrow areas, five spoils areas, and one construction camp along the 84-kilometer (52-mile) construction corridor. Estimated emission rates would exceed the PM_{10} General Conformity threshold for a nonattainment area (see Table 6-73). The PM_{10} exceedance would primarily be the result of earthmoving activities. Dust abatement measures, assumed to be 70 percent effective (DIRS 155557-Clark County 2001, p. 4-63), would reduce emissions by a significant amount.

Table 6-72. Emission rates from Valley Modified Corridor construction in the nonattainment area.

Activity and emission	Emission rate (kilograms per year)
Earthmoving, PM_{10}	110,000
Vehicle, PM_{10}	14,000
Vehicle, carbon monoxide	98,000

a. To convert kilograms to pounds, multiply by 2.2046.

Table 6-73. Particulate matter (PM_{10}) and carbon monoxide air quality impacts (kilograms per year)[a] from Valley Modified Corridor construction in the nonattainment area.

Criteria pollutant/threshold	Threshold level[b]	Percent of threshold[c]		
		Earthmoving	Vehicles	Total
PM_{10}				
General Conformity	63,500 (serious)	170	22	190
Prevention of Significant Deterioration	227,000	48	6	54
Carbon monoxide				
General Conformity	90,700	NA[d]	110	110
Prevention of Significant Deterioration	227,000	NA	43	43

a. Kilograms per year; to convert kilograms to pounds, multiply by 2.2046.
b. Sources: 40 CFR 52.21 and 93.153.
c. Numbers are rounded to two significant figures.
d. NA = not applicable.

If DOE selected the Valley Modified Corridor for the construction and operation of a branch rail line, the final plans, specifications, and estimates would require adherence to the Clark County Health District PM_{10} emissions control measures. These measures are being developed in the Particulate Matter State Implementation Plan (DIRS 155557-Clark County 2001, all). Implementation of the comprehensive measures should enable rail line construction to start. The purpose of the measures under development is not to prohibit construction activity, but to enable it within the Environmental Protection Agency air quality requirements. Because the estimated impacts to air quality in the Las Vegas Valley air basin would exceed the General Conformity thresholds for carbon monoxide and PM_{10} in a nonattainment area, DOE would have to implement mitigation measures if it selected the Valley Modified Corridor. Under the construction design analyzed above, one crew at a time would construct the branch rail line from beginning to end over about 40 months, and the emissions in the Las Vegas Valley air basin would occur over about 21 months. A potential mitigation measure would be to have two crews construct the line at half the pace from each end of the corridor. Under this plan, the emissions in the basin would occur over the full 40 months, which would result in a decrease of about half in the emission rates, which would reduce the impacts listed above to levels at or less than the General Conformity thresholds. In addition, as part of final construction planning DOE would plan to use dust control measures and ensure fuel efficiency to reduce emissions. These measures should result in emissions below the General Conformity threshold levels.

The Valley Modified Corridor includes the Indian Hills Alternate, Sheep Mountain Alternate, and Valley Connection. The Sheep Mountain Alternate and Valley Connection are entirely in the nonattainment area, whereas only half of the Indian Hills Alternate is in the nonattainment area. The rail extents of the Indian Hill Alternate and the Valley Modified Corridor in the nonattainment area are equivalent. Therefore, no greater or smaller air quality impacts would result from selection of the Indian Hill Alternate. The Sheep Mountain Alternate and Valley Connection, if used, would add 3 and 7 kilometers (1.9 and 4.3 miles) of rail, respectively, to the length of the Corridor. Therefore, air quality impacts would be slightly but not significantly (less than 10 percent) greater if these variations were used.

Operations. Fuel consumption by diesel train engines operating along the rail corridor would emit carbon monoxide, nitrogen dioxide, and particulate matter (PM_{10} and $PM_{2.5}$). Based on the Federal standards for locomotives (40 CFR 92.005), there are no emission standards for sulfur dioxide.

In attainment areas, the pollutant concentrations in the air would increase slightly during the passage of a train, but the emissions from one or two trains a day would not exceed the ambient air quality standards. However, the Valley Modified Corridor would include a route through the Las Vegas Valley air basin, which is in nonattainment for carbon monoxide and PM_{10}. The air quality impacts to this air basin from train operation along the Valley Modified Corridor would be a small contribution in comparison to the amount of pollutants emitted by automotive travel in the basin. Thus, emissions from train operations in the Las Vegas Valley air basin would not produce further violations of the ambient air quality standards.

6.3.2.2.5.3 Valley Modified Rail Hydrology

Surface Water

Chapter 3, Section 3.2.2.1.3, notes that there are no surface-water resources along the Valley Modified Corridor, including its variations.

Table 6-74 lists flood zones identified along the Valley Modified Corridor and its variations. The Federal Emergency Management Agency maps from which DOE derived the flood zone information provided coverage for about 75 percent of the corridor length. The corridor crosses only two different 100-year flood zones or flood zone groups before entering the Nevada Test Site. Of the three variations, the Indian Hills Alternate would lessen the number of flood zones to one; the other two segments would have no change. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3,

Table 6-74. 100-year flood zones crossed by the Valley Modified Corridor and its variations.[a,b]

Corridor portion	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (Yes or No)
Dry Lake to Yucca Mountain	0.1[e]	Unnamed creek NW of the city of Las Vegas (intermittent)	N
	1.2[f]	Drainage (projected) west of Indian Springs Air Force Auxiliary Base (intermittent)	Y-3
Variation			
1. Valley Connection	None	Located at the origin of the corridor	
2. Sheep Mountain Alternate	None	Located to the north of the corridor	
3. Indian Hills Alternate	None	Located to the south of the corridor	

a. Areas where natural floodwater movement could be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Clark and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).

b. Approximately 25 percent of the Valley Modified Corridor is not available on Federal Emergency Management Agency maps because that portion of the route is on the Nevada Test Site and the Nellis Air Force Range.

c. To convert kilometers to miles, multiply by 0.62137.

d. Certain 100-year flood zones can be avoided by corridor variations. These are identified with a "Y" (yes) and a number representing the specific variation(s) from the second half of the table that avoids the specific flood zone.

e. Limited information due to the Nellis Air Force Range.

f. Projected from limited data. Specific area not covered by Federal Emergency Management Agency maps; values were extrapolated from the closest maps.

Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Valley Modified corridor passes).

The estimated amount of water needed for construction of a rail line in the Valley Modified Corridor for soil compaction, dust control, and workforce use would be about 395,000 cubic meters (320 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 20 groundwater wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 20,000 cubic meters (16 acre-feet). Most (90 percent) of the water would be used for compaction of fill material. The estimate of fill quantities needed for construction would vary if DOE used either of the variations. The Indian Hills Alternate would increase the total water demand for the Valley Modified Corridor, but only by 6 percent.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the Valley Modified Corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-75 summarizes the designation status of the hydrographic areas associated with the Valley Modified Corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins. Use of either variation would make no notable change in the status of hydrographic areas crossed.

Table 6-75. Hydrographic areas along the Valley Modified Corridor and its variations.[a]

Corridor description	Hydrographic areas	Designated Groundwater Basins	
		Number	Percent of corridor length
Valley Modified Corridor	6	3	70
Variations	6	3	70

a. All three variations (Indian Hills Alternate, Sheep Mountain Alternate, and Valley Connection) would cross the same six hydrographic areas (two with slightly different crossing distances) and the same three designated groundwater basins which, rounded to the nearest 10 percent, would represent the same portion of the total corridor.

The withdrawal of 20,000 cubic meters (16 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 20 wells along the corridor would mean that hydrographic areas would have multiple wells. As indicated in Table 6-75, about 70 percent of the corridor length is over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. With such a large portion of the corridor over these basins, however, this would mean trucking water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources are not adversely affected.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Valley Modified corridor would require about 21,000 tanker-truck loads of water or about 20 truckloads each day. Again, water obtained from permitted sources, which would provide water in allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

6.3.2.2.5.4 Valley Modified Rail Biological Resources and Soils

Construction. The construction of a rail line in the Valley Modified corridor, including its variations, would disturb approximately 5 square kilometers (1,200 acres) of land (Table 6-71). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. Table 6-76 compares the approximate area of disturbance in each land-cover type along the Valley Modified Corridor, including its possible variations, to the amount of land area within each land-cover type in Nevada. In addition, the table lists the percentage of the area that would be disturbed. The fraction disturbed for each cover type would be very small. The disturbance would not have a discernible impact on any land-cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to that in the corridor.

This corridor, including its variations, passes through desert tortoise habitat along its entire length, so construction activities would disturb approximately 5 square kilometers (1,200 acres) of desert tortoise habitat, some of which is designated as critical habitat. Construction activities could kill individual desert tortoises, and the presence of a rail line could disrupt movements of individuals. However, desert tortoise abundance is low along this corridor (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411) so losses would be few, and would be unlikely to affect the regional population. Relocation of tortoises along the route prior to construction would minimize losses of individuals. The long-term presence of a rail line could block movements of individual tortoises. DOE would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) regarding this species if it selected this corridor, and would implement all terms and conditions required by the Service.

Two populations of Parish scorpionweed and one of Ripley's springparsley (a Bureau of Land Management sensitive species) occur in the corridor and could be affected directly or indirectly by land-clearing activities. The locations of these populations would be identified though surveys prior to disturbance and would be avoided to the extent possible.

Table 6-76. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Valley Modified Corridor.[b,c]

Land cover type	Percent of corridor length	Area disturbed	Area in Nevada	Percent disturbed
Agriculture	0.0	0.00	5,200	0.00
Blackbrush	0.0	0.00	9,900	0.00
Creosote-bursage	79.0	4.03	15,000	0.026
Grassland	0.0	0.00	2,800	0.00
Greasewood	0.0	0.00	9,500	0.00
Hopsage	0.0	0.00	630	0.00
Juniper	0.0	0.00	1,400	0.00
Mojave mixed scrub	15.9	0.81	5,600	0.014
Pinyon-juniper	0.0	0.00	15,000	0.00
Playa	0.6	0.03	7,000	<0.001
Sagebrush	0.0	0.00	67,000	0.0
Sagebrush/grassland	0.0	0.00	52,000	0.0
Salt desert scrub	4.5	0.23	58,000	<0.001
Urban		ND[d]	2,400	ND

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.

There are 46 populations of 11 sensitive plant species outside of the 400-meter (0.25-mile)-wide corridor, but within 5 kilometers (3 miles) of Sheep Mountain Alternate (see Appendix J, Section J.3.1.2 for a list of corridor variations). An additional five populations of two sensitive plant species are outside the corridor but within 5 kilometers of the Indian Hills Alternate. The use of either alternate would avoid one population of desert bearpoppy. These populations would not be affected because land disturbance would not extend to these areas and changes would be unlikely in the aquatic or soil environment as a result of construction or the long-term presence of a railroad.

Several designated game habitat areas for bighorn sheep, mule deer, or quail occur within 5 kilometers (3 miles) of the corridor. Larger game animals occupy large home ranges and could easily traverse the distance between the designated habitat and the corridor. Construction activities probably would disturb individuals or groups of animals and they would avoid construction areas.

The Indian Hills Alternate would cross one herd management area for wild horses and burros (DIRS 104593-CRWMS M&O 1999, p. 3-29). Construction in this area would result in the loss of a small amount of habitat and probably would disturb animals or their movements for the duration of the activity.

No springs, perennial streams, or riparian areas occur in this corridor or its variations and, therefore, impacts to biological resources associated with these areas and located within 5 kilometers (3 miles) of the corridor would be unlikely. The corridor and variations cross a number of ephemeral streams that may be classified as waters of the United States, although no formal delineations have been made (DIRS 104593-CRWMS M&O 1999, p. 3-29). DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits, if necessary. Some changes to local drainage along a branch rail line would be likely; DOE would design the rail line to accommodate existing drainage patterns.

This corridor would cross two Wilderness Study Areas. Construction of a railroad in these areas would be incompatible with a Wilderness designation. Although the Bureau considers these Wilderness Study

Areas unsuitable for inclusion in the National Wilderness System, DOE would have to consult with the Bureau before it could build a branch rail line.

Soils in and adjacent to the corridor would be disturbed on approximately 5 square kilometers (1,200 acres) of land during construction of the railroad. Impacts to soils in the corridor [4.4 square kilometers (1,100 acres)] would be small, but could occur throughout construction. Impacts to disturbed areas outside the corridor would be transitory. DOE could reclaim these areas as practicable.

Shrink-swell soils occur along much of the corridor, including its variations, as does the potential for blowing soils. The presence of such soils could influence the amount of area disturbed by construction because soils in the vicinity of the railroad would have to be stabilized. Disturbance during construction would increase the amount of soil that could be transported by wind because the existing vegetation would be disturbed, at least temporarily. Revegetation after construction or other means of soil stabilization could minimize the amount of wind-borne soil.

As stated in Chapter 3, Section 3.2.2.1.4, variations identified for the Valley Modified Corridor could avoid some biological resources, as listed in Table 6-77.

Table 6-77. Biological resources avoided by Valley Modified Corridor variations.[a]

	Occurrence of resource			
	For unvaried segment of corridor		Occurrence avoided by variation	
Alignment variation resource	In corridor[b]	Within 5 km[c]	In corridor	Within 5 km
Sheep Mountain Alternate				
Sensitive species–desert bearpoppy	0	1	0	11
Indian Hills Alternate				
Sensitive species–desert bearpoppy	0	1	0	11

a. Variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25 mile)], but avoided by the variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the variation.

6.3.2.2.5.5 Valley Modified Rail Cultural Resources

Construction. Cultural field studies in the area of the Valley Modified Corridor indicated that the area crossed by the corridor has the potential for relatively high densities of archaeological and historic sites. The corridor, including the Sheep Mountain Alternate, passes within 3 kilometers (1.9 miles) of three properties listed on the *National Register of Historic Places*: Tule Springs Archaeological Site, Tule Springs Ranch District, and the Corn Creek Campsite (DIRS 155826-Nickens and Hartwell 2001, Table 6). Direct impacts on these properties from rail line construction activities would be unlikely. The Bureau of Land Management Las Vegas District predicts that the Indian Springs Valley has the highest possible density of unrecorded significant cultural resources in Clark County. An archaeological records search yielded 19 previously recorded sites along the corridor and its variations (see Appendix J, Section J.3.1.2), 11 of which are considered potentially eligible for the *National Register of Historic Places* (Chapter 3, Section 3.2.2.1.5). Known historic sites that could be affected by rail construction activities include early railroad construction camps along the Union Pacific line near Apex and the historic Las Vegas and Tonopah Railroad (unvaried corridor segment, Sheep Mountain Alternate, and Indian Springs Alternate), as well as the original grade of that railroad. This corridor passes through Camp Desert Rock, a significant historic military site southwest of Mercury.

The Southern Paiute used Indian Springs Valley. There were several early historic period villages at springs such as Indian Springs, Tule Springs, and Corn Creek, and at other locations north of Las Vegas. Some of these locations could be affected by rail line construction activities along the corridor or the Sheep Mountain or Indian Hills Alternates.

The Valley Modified Corridor passes within about 1 kilometer (0.6 mile) of the Las Vegas Paiute Indian Reservation in the northeastern part of the Las Vegas Valley. The corridor would not affect identified cultural resources on the reservation.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.5.6 Valley Modified Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Valley Modified branch rail line would be small (Table 6-78). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available (Table 6-79).

Table 6-78. Impacts to workers from industrial hazards during rail construction and operations for the Valley Modified Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved worker		
Total recordable cases[c]	32	73
Lost workday cases	16	40
Fatalities	0.04	0.20
Noninvolved worker		
Total recordable cases	1.9	4.1
Lost workday cases	0.7	1.5
Fatalities	0.002	0.004
Totals		
Total recordable cases	34	77
Lost workday cases	16	41
Fatalities	0.05	0.20

a. Totals for 40 months for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injuries and illness.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Valley Modified rail corridor. Table 6-80 lists the incident-free impacts, which include transportation along the Valley Modified corridor and along railways in Nevada leading to a Valley Modified branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

6.3.2.2.5.7 Valley Modified Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction and operation of a branch rail line in the Valley Modified Corridor.

Construction. The length of the Valley Modified Corridor, 159 kilometers (98 miles), is the most important factor that would determine the number of construction workers required. The construction of a branch rail line in this corridor would require workers laboring for approximately 810,000 hours or 405 worker years during the 40-month construction period. This rail line would require two temporary construction camps to house workers (DIRS 104595-CRWMS M&O 1999, all).

Employment

DOE anticipates that the total (direct and indirect) employment in the region of influence would peak in 2007 at about 245 jobs. Approximately 243 of the workers would come from Clark County, 2 from Nye County, and none from Lincoln County. The increase in employment would represent less than 1 percent of the employment baselines. Employment of Valley Modified Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth (2009 to 2010) of 15,240 jobs in the region of influence would be reduced by 191. The expected addition of 14,886 jobs in Clark County would be reduced by 189, and the expected growth of 330 jobs in Nye County would be reduced by 2. The expected growth of 24 jobs in Lincoln County would be unaffected. DOE anticipates

Table 6-79. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Valley Modified Corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	8,000,000	0.1	0.02
Commuting workers	24,000,000	0.2	0.03
Subtotals	*32,000,000*	*0.4*	*0.05*
Operations[c]			
Commuting workers	52,000,000	0.5	0.07
Totals	***84,000,000***	***0.9***	***0.12***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 40 months for construction.
c. Totals for 24 years for operations.

Table 6-80. Health impacts from incident-free Nevada transportation for the Valley Modified Corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	670	710
Estimated latent cancer fatalities	0.02	0.27	0.28
Public			
Collective dose (person-rem)	7	20	26
Estimated latent cancer fatalities	0.003	0.01	0.01
Estimated vehicle emission-related fatalities	0.002	0.009	0.011

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

that project-related workers not moving to Valley Modified Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in the region of influence from the construction of a Valley Modified branch rail line, which would lag behind increases in employment, would peak in 2009 at about 219 persons. About 216 persons would reside in Clark County and 3 in Nye County. Population increases would be unlikely in Lincoln County. The impact to the population would be less than 1 percent of the Clark and Nye County population baselines. Because the expected increase in population would be so small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Real disposable income, Gross Regional Product, and State and local government expenditures would rise during construction. The expected peak change in annual levels of these economic measures in the region of influence for a Valley Modified Corridor would be about $7.4 million in 2009 for real disposable income; $12.5 million in 2007 for Gross Regional Product; and $722,000 in 2009 for State and local expenditures. The impacts of these changes would be primarily confined to Clark County, where the workers would live and where they would purchase goods and services. The construction-related impacts would be less than 1 percent of the baseline values for all measures. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition and Operations Period. As the economy bridged the period between construction and operation of a Valley Modified branch rail line, the region of influence would continue to experience growth in the labor force and in residential population.

Employment and Population

Estimated direct employment for the operation of a branch rail line in the Valley Modified Corridor would average 36 workers. Total increase in employment in the three-county region of influence would average about 52 jobs over the 24-year operations period (2010 to 2033). DOE anticipates that all jobs would be in Clark County. In the region of influence, the average change in population during operations would be about 137 persons, 134 of whom would reside in Clark County. The impact to Clark County population and employment would be less than 1 percent of the baselines. Because the impact from increases in employment and population would be small, impacts to schools or housing would be unlikely.

Economic Measures

In the region of influence the greatest estimated increase in real disposable income attributable to the operation of a branch rail line in the Valley Modified Corridor ($3.6 million) would occur in 2033; the average increase for the 24-year operation would be $3.1 million. The change in real disposable income would be less than 1 percent of the baseline in the three counties. The average increase in Gross Regional Product would be about $3.6 million, or less than 1 percent of the baselines. The average State and local government expenditures would be approximately $482,000. The impact of additional expenditures by State and local governments would be less than 1 percent of the baselines. Virtually all of the economic activity related to the branch rail line would occur in Clark County.

The results of the detailed analysis performed for the Valley Modified Corridor, driven by the length of the corridor, are representative of the variations listed in Appendix J, Section J.3.1.2. The lengths of the variations are similar those listed in Table 6-71.

6.3.2.2.5.8 Valley Modified Rail Noise and Vibration

The Valley Modified Corridor passes north of Las Vegas and follows U.S. Highway 95 west past the small communities of Indian Springs, Cactus Springs, and Mercury (a Federal installation). Over its full length, the corridor is on Federal land set aside for use by DOE or the U.S. Air Force or managed by the Bureau of Land Management. Land west of the North Las Vegas area has few farms and most of the land is undeveloped.

The corridor meets the Union Pacific mainline near the Apex and Dike sidings in northeast Clark County. The County and the Bureau of Land Management have set aside land for an industrial park in this area. The nighttime noise benchmark of 50 dBA would be exceeded by estimated noise levels north of Las Vegas (Table 6-81). The corridor passes within 1 kilometer (0.6 mile) of the Las Vegas Paiute Indian Reservation. The Indian Hills Alternate (Appendix J, Section J.3.1.2) passes about 0.5 kilometer (0.3 mile) south of the Nevada penal institution at Indian Springs. Estimated noise levels at the penal institution from the Indian Springs Alternate would be 65 dBA.

Because a branch rail line would pass near some communities (including the Indian Springs penal institution), there would be a potential for noise impacts from both construction and operations. Corridor variations west of Indian Springs would not affect rural communities (Appendix J, Section J.3.1.2). The estimated population residing within 2 kilometers (1.3 miles) of the Valley Modified Corridor in 2035 would be about 190 persons. As discussed in Section 6.3.2.1, in areas where a branch rail line or variation passes near a community, train speeds could be limited to the extent necessary to ensure that noise was below levels listed as accepted noise standards.

Vibration. The Valley Modified branch rail line and its variations would be distant [more than 200 meters (660 feet)] from historic structures and buildings. There are no known ruins of cultural significance along the corridor. Therefore, vibration impacts to structures would be unlikely. The small number of trips (two per day) and the small train size would result in low levels of rail-induced ground vibration.

Table 6-81. Estimated propagation of noise (dBA) from the operation of a waste transport train with two locomotives in communities near the Valley Modified Corridor.[a]

Corridor/community	Distance (kilometers)[a]	Estimated noise (dBA)[b]
Valley Modified		
North Las Vegas	1	57
Indian Springs	1.6	48.1
Cactus Springs	1.8	45.5
Indian Springs Alternate		
Indian Springs	2[c]	43.1
Cactus Springs	4[c]	27.6
Mercury[d]	2[c]	43.1

a. To convert kilometers to miles, multiply by 0.62137.
b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
c. Noise estimates at distances greater than 2 kilometers (1.2 miles) have large uncertainty.
d. Federal installation.

6.3.2.2.5.9 Valley Modified Rail Utilities, Energy, and Materials

Table 6-82 lists the use of fossil fuels and other materials in the construction of a Valley Modified branch rail line.

Table 6-82. Construction utilities, energy, and materials for a Valley Modified branch rail line.

Route	Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
Valley Modified	160	13 - 14	270 - 280	22 - 23	130

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.3 IMPACTS OF NEVADA HEAVY-HAUL TRUCK TRANSPORTATION IMPLEMENTING ALTERNATIVES

This section describes the analysis of human health and safety and environmental impacts for five implementing alternatives that would employ heavy-haul trucks to transport rail shipping casks containing spent nuclear fuel and high-level radioactive waste in Nevada. DOE has identified five highway routes in Nevada for potential use by the heavy-haul trucks to transport the casks. The casks would be transported to the repository from an intermodal transfer station along a mainline railroad where they would be loaded onto the heavy-haul trucks from railcars. The trucks would also transport empty casks from the repository back to the intermodal transfer station for loading back onto railcars.

INTERMODAL TRANSFER STATION AND NAVAL SPENT NUCLEAR FUEL

Under the mostly legal-weight truck scenario, DOE would use the services of a commercial intermodal operator for the transfer of naval spent nuclear fuel shipments. This EIS assumed that DOE would not build an intermodal transfer station to handle those shipments. Because only 300 naval spent nuclear fuel casks would arrive in Nevada by rail over 24 years, the impacts of intermodal transfer operations would be considerably less than those for the mostly rail scenario. On average, the intermodal transfers would occur for about 2 weeks every 5 months to remove five casks from each train shipment. A staff of 20 would work only during these rail shipments.

DOE would locate an intermodal transfer station at one of three potential locations in Nevada near existing rail lines and highways: (1) near Caliente, (2) northeast of Las Vegas (Apex/Dry Lake), or (3) southwest of Las Vegas (Sloan/Jean). Caliente is the originating location for three of the routes that heavy-haul trucks could use to ship spent nuclear fuel and high-level radioactive waste to the repository. There is one potential route each associated with the Apex/Dry Lake and Sloan/Jean locations (Figure 6-20).

For convenience and as shown in the figure, the five highway routes have been named the Caliente, Caliente/Chalk Mountain, Caliente/Las Vegas, Apex/Dry Lake, and Sloan/Jean routes. DOE considers these routes to be feasible for heavy-haul trucks to use in transporting large rail casks to and from the repository. The routes were compiled from a selection of highways in Nevada that the State has designated for use by heavy-haul trucks (DIRS 155347-CRWMS M&O 1999, Request #046). They include highways that were identified in a study by the College of Engineering at the University of Nevada, Reno, for the Nevada Department of Transportation (DIRS 103072-Ardila-Coulson 1989, all). This study provided a "preliminary identification of Nevada highway routes that could be used to transport current shipments of Highway Route-Controlled Quantities of Radioactive Materials and high-level radioactive waste." They also include highways studied by the Transportation Research Center at the University of Nevada, Las Vegas, that characterized "rail and highway routes which may be used for shipments of high-level nuclear waste to a proposed repository at Yucca Mountain, Nevada" (DIRS 103462-Souleyrette, Sathisan, and di Bartolo 1991, all).

This section evaluates impacts in Nevada for each route and associated intermodal transfer station. The evaluation addresses (1) upgrading highways to accommodate frequent heavy-haul truck shipments, (2) constructing and operating an intermodal transfer station, and (3) making heavy-haul truck shipments. With the exception of Interstate System Highways, upgrades to existing Nevada highways would be necessary to accommodate the heavy-haul trucks.

The analysis of impacts for each of the five Nevada heavy-haul truck implementing alternatives assumed the national mostly rail transportation scenario. Therefore, the analysis included the impacts of legal-weight truck transportation from six commercial generators that do not have the capability to handle or load a large rail cask. About 1,079 legal-weight truck shipments would enter Nevada and travel to the repository. These trucks would use the same transport routes and carry about the same amounts of spent nuclear fuel per shipment as those for the mostly legal-weight truck scenario discussed in Section 6.3.1.

The analysis evaluates impacts for the following environmental resource areas: land use and ownership; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management.

Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.1 Impacts Common to Nevada Heavy-Haul Truck Implementing Alternatives

Nevada highways upgraded for heavy-haul truck use would allow routine, safe use in year-round operations. Upgrades would include reconstruction of some highway sections, especially in areas where spring and fall thaws and freezes make the highways susceptible to damage by heavy vehicles (frost-restricted areas). In addition, new turnout lanes at frequent intervals along two-lane highways would allow other traffic to pass the slower heavy-haul vehicles. Highway shoulders would be widened and road surfaces would be improved in many areas. Interstate highways would not be improved because they already meet standards that upgrades to other Nevada highways for heavy-haul truck shipments would follow.

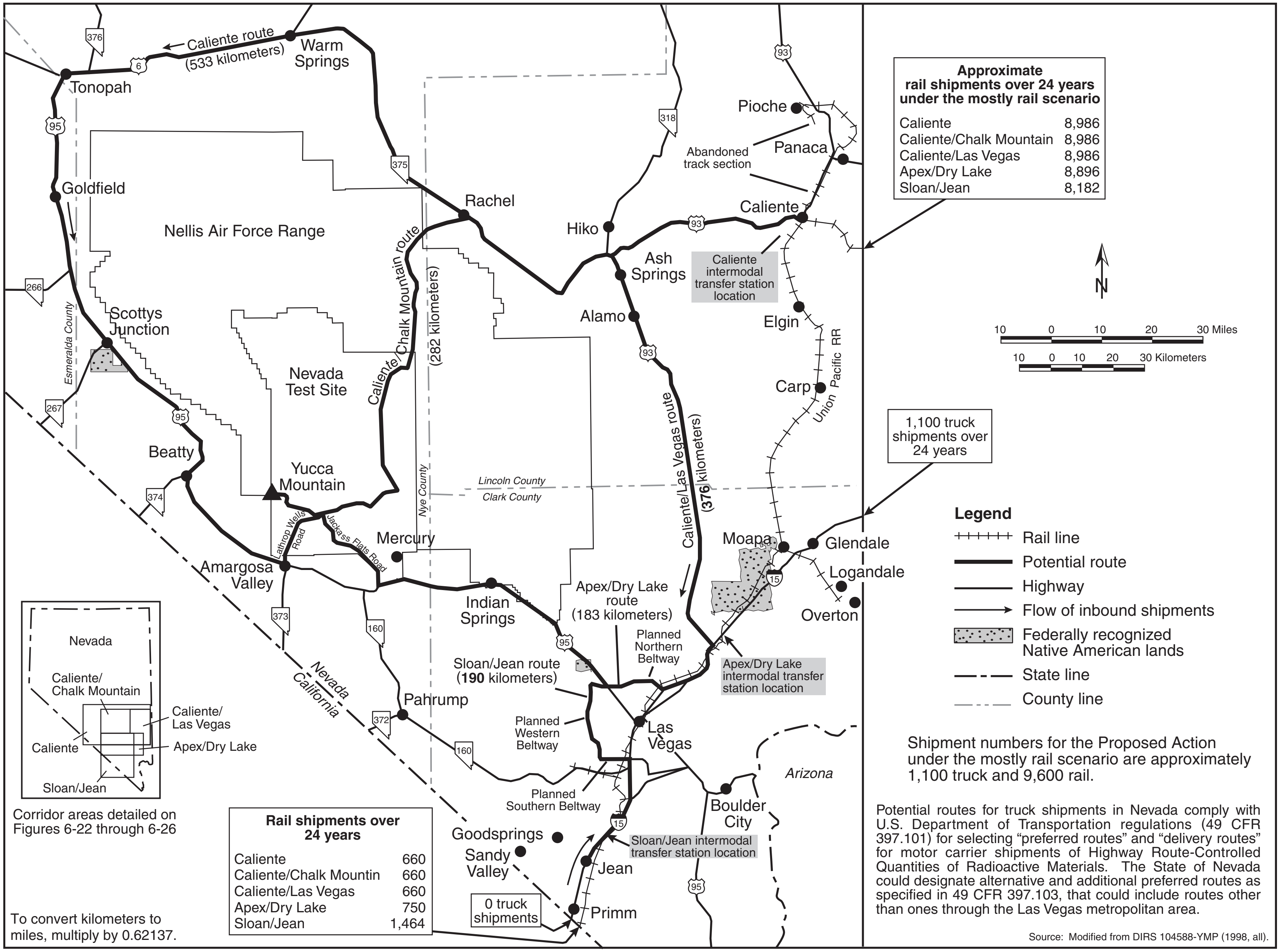


Figure 6-20. Potential routes in Nevada for heavy-haul trucks and estimated number of shipments for each route.

Even with the highway upgrades, heavy-haul trucks would cause delays for other vehicles because of their size and slower travel speeds. On most of the highways in Nevada that heavy-haul shipments would use, traffic volumes are classified as *level of service Class A* (DIRS 103255-CRWMS M&O 1999, p. 3-11), which means that traffic flows freely without delay (see Chapter 3, Section 3.2.2.2.11, for a description of all levels of service). The addition of 11 round trips each week to the traffic flow on these highways would not lead to a change in the average level of service. However, some traffic in lanes traveling with the vehicles would experience delays and short queues could form between turnout areas. In congested areas, such as the Las Vegas metropolitan area, where the level of service for the planned Las Vegas Beltway could be Class C or lower during non-rush-hour times, large slow-moving vehicles with their accompanying escort vehicles could present a temporary but large obstruction to traffic flow. Because disruptions on congested highways often continue after the removal of the cause, the duration of a traffic flow disruption would be longer than the time the vehicle would travel on the highway.

An intermodal transfer station would be common to all five heavy-haul truck implementing alternatives. Figure 6-21 shows the locations in Nevada that DOE is considering for such a station. Station construction would take about 18 months. The station would be a fenced area of about 250 by 250 meters (820 by 820 feet) and a rail siding that would be about 2 kilometers (1.25 miles) long. The estimated total area occupied by the facility and support areas would be 200,000 square meters (50 acres). It would include rail tracks, two shipping cask transfer cranes (one on a gantry rail and a backup rubber-tired vehicle), an office building, and a maintenance and security building. It would also have connecting tracks to an existing mainline railroad and storage and transfer tracks inside the station boundary. The maintenance building would provide space for routine service and minor repairs to the heavy-haul trailers and tractors. The station would have power, water, and other services. Diesel generators would provide a backup electric power source. The station would have the capacity to allow an intermodal transfer rate of 22 rail casks a week (11 loaded casks to the repository, 11 empty casks returned to the commercial and DOE sites).

Operations at an intermodal transfer station would include switching railcars carrying spent nuclear fuel and high-level radioactive waste casks from mainline railroad trains to the station's side track; queuing railcars on the side track for movement to the intermodal transfer area; moving railcars carrying loaded casks from the side track into position to transfer the casks to heavy-haul trucks; and using the facility crane to transfer loaded casks from railcars to heavy-haul trucks. The station would reverse this sequence of operations for empty casks returning from the repository.

The estimated life-cycle cost to construct and operate an intermodal transfer station and to operate heavy-haul trucks in Nevada would range from $387 million to $669 million (2001 dollars), depending on the alternative.

This section discusses impacts for the analysis areas that would be common to all five heavy-haul truck implementing alternatives. It includes impacts for upgrading Nevada highways for use by heavy-haul trucks, constructing and operating an intermodal transfer station, and heavy-haul truck transportation of shipping casks, both loaded and empty. DOE evaluated these impacts as described in Section 6.3. Section 6.3.3.2 discusses impacts that would be unique to each heavy-haul truck transportation implementing alternative.

6.3.3.1.1 *Common Route Land Use and Ownership Impacts*

Intermodal Transfer Station Construction. Land-use impacts from an intermodal transfer station would center on the station itself because the railroad lines and the highways that DOE would use already exist and their intended use would not change. The construction of an intermodal transfer station would change the land uses and ownership (organizational control) of about 0.2 square kilometer (50 acres) of property. This land would become the responsibility of DOE or possibly a transportation operating

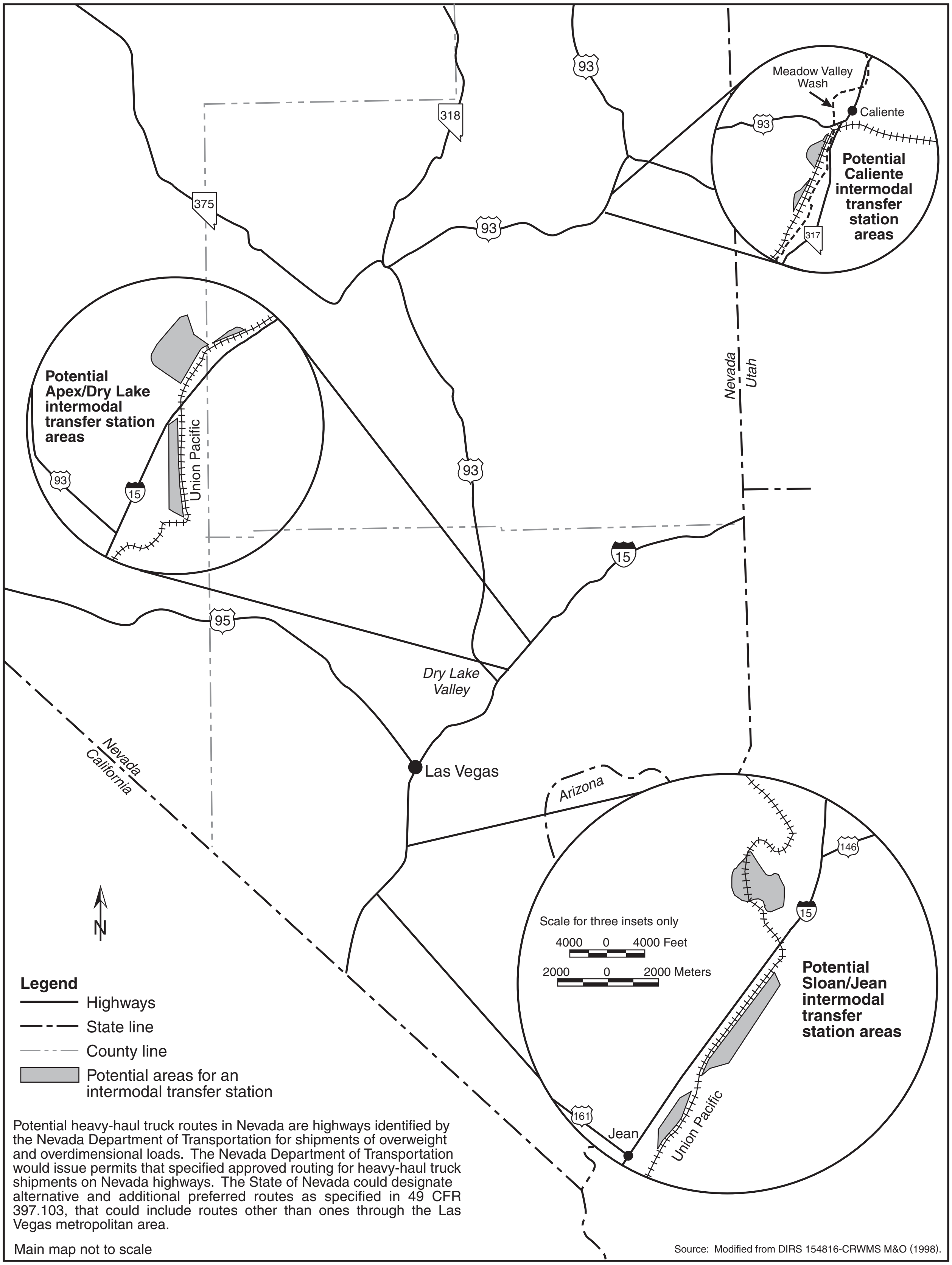


Figure 6-21. Potential locations for an intermodal transfer station.

company. An intermodal transfer station would be in an area used for industrial and commercial activities or adjacent to existing roads and railways. Because the land area would be small, fencing around an intermodal transfer station would have no significant impacts on other land uses. Because of the station's use and proximity to industrial and commercial facilities or existing roads and rail lines, land use impacts would be small. DOE would build a Caliente intermodal transfer station, located near the entrance to Kershaw-Ryan State Park, on lands currently used for industrial and commercial purposes. Because of this, there should be no additional impact to land use.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Intermodal transfer station operations (arriving and departing trains, arriving and departing heavy-haul trucks, intermodal transfers, and maintenance and inspection activities) would be confined to the same areas that were disturbed during construction, so no additional land disturbance would take place. There would be no significant impacts to land use of the proposed facility locations. Only limited land-use impacts would result from heavy-haul truck operations on Nevada highways. Erosion along these highways would be managed as it is now. Because new road construction would not be needed, additional land and soil disturbance would occur only along existing roads and within existing rights-of way. Other land-use and ownership impacts would differ among the implementing alternatives. These impacts are described in Section 6.3.3.2.

6.3.3.1.2 *Common Route Air Quality Impacts*

The emissions of criteria pollutants [carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter (PM_{10}), lead, and ozone] are regulated under the Clean Air Act. Ozone would not be directly released during heavy-haul truck route construction and operation activities. However, ozone precursors (nitrogen dioxide and volatile organic carbon compounds) would be released due to fuel use by construction equipment. The estimated annual emission rates of nitrogen dioxide and volatile organic carbon compounds would be small in comparison with regulatory standards (40 CFR 52.21). In addition, lead emissions would not result from heavy-haul truck route construction and operation activities. The construction and operation activities discussed in this section would not be a significant source of ozone or lead.

DOE conducted a conformity review using the guidance in DIRS 155566-DOE (2000, all) for transportation activities under the heavy-haul truck implementing alternative. This review focused on the emission of carbon monoxide and PM_{10}. The Las Vegas air basin is in nonattainment status for carbon monoxide, which is largely a result of on-road sources (DIRS 156706-Clark County 2000, Appendix A, Table 1-3). During construction, transportation of personnel, materials, and supplies; construction of an intermodal transfer station; and highway construction and upgrade activities in the nonattainment area (including accelerated construction of the Las Vegas Beltway) would result in carbon monoxide emissions in the nonattainment area. During operations, transportation of personnel, materials, and supplies and transportation of spent nuclear fuel and high-level radioactive waste would result in carbon monoxide emissions in the nonattainment area. The review determined that during the construction phase total carbon monoxide emissions would exceed the General Conformity threshold level in the nonattainment area only for the Caliente/Las Vegas route (110 percent of threshold). All other nonattainment area construction and operations emissions in the nonattainment area would not exceed the General Conformity threshold level. The maximum emissions would be 100 metric tons (110 tons) per year (110 percent of threshold) during construction ; this estimate is 0.11 percent of the 2000 daily carbon monoxide inventory of the Las Vegas air basin. Maximum total emissions during operations would be 73 metric tons (80 tons) per year (80 percent of threshold); this estimate is 0.08 percent of the 2000 daily carbon monoxide inventory of the Las Vegas air basin.

The Las Vegas air basin is also in nonattainment status for PM_{10}, which is largely a result of construction activities (DIRS 155557-Clark County 2001, Tables 3-8 and 5-3). The conformity review determined that the fugitive dust emissions from the construction of the intermodal transfer facilities and highway construction and upgrade activities in the nonattainment area (including accelerated construction of the Las Vegas Beltway) would just exceed General Conformity threshold levels for the Caliente/Las Vegas route (100 percent of threshold). The maximum emissions would be 66 metric tons (73 tons) per year (100 percent of threshold) during construction; this estimate is 0.04 percent of the annual and daily 2001 PM_{10} inventory of the Las Vegas air basin.

The General Conformity Threshold levels are exceeded for carbon monoxide (110 percent of threshold) and PM_{10} (100 percent of threshold) during construction of the Caliente/Las Vegas route. The above-threshold emissions would occur over a 1.2-year period in the nonattainment area. During the remaining construction time for this route, construction activities and, therefore, emissions would occur largely outside the nonattainment area. Outside the nonattainment area, emissions levels would be significantly below the Prevention of Significant Deterioration levels (carbon monoxide—43 percent of threshold and PM_{10}—29 percent of threshold).

The DIRS 155112-Berger (2000, p. 56) estimate for transportation of radioactive materials only for heavy-haul truck transport for 2020 is 0.54 metric ton (0.59 ton) per day. The Berger estimate is largely the result of emissions from collateral traffic congestion. Although DOE believes the estimate is high, a value of 0.54 metric ton per day, 11 round trip shipments per week, 52 weeks per year, would result in about 123 metric tons (135 tons) of carbon monoxide per year, which would exceed the 91 metric tons (100 tons) per year General Conformity threshold, but would be 0.08 percent of the annual and daily 2001 PM_{10} inventory of the Las Vegas air basin.

Highway Construction and Upgrades. Construction and upgrade activities would occur in Nevada along any of the five heavy-haul alternatives (see disturbed area estimates under the Land Use and Ownership discussions in Section 6.3.3.2. These activities would result in the release of criteria pollutants. Fuel consumption during construction activities would result in releases of criteria pollutants [carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter (PM_{10})]. Construction activities would also release particulate matter in the form of fugitive dust from such activities as excavation and truck traffic. The analysis for the three heavy-haul truck routes that would pass through the Las Vegas Valley air basin included acceleration of the Las Vegas Beltway project from its scheduled completion in 2020 to a completion date of 2010.

Most of the road upgrades would occur in areas that are in attainment for all criteria pollutants. If construction activities were conducted in the Las Vegas Basin, which is in nonattainment for PM_{10} and carbon monoxide, additional measures would be necessary to reduce the PM_{10} and carbon-monoxide emissions, in accordance with the Clark County PM_{10} State Implementation Plan (DIRS 155557-Clark County 2001, all). Appendix G, Section G.1.4.1, describes the method used to determine PM_{10} emissions from earthmoving activities. This method takes no credit for dust suppression measures. However, the analysis assumed dust suppression for the transportation construction emissions described here and in the conformity review; dust suppression was assumed to reduce PM_{10} emissions by 70 percent. Appendix G, Section G.1.4.5, describes the method used to determine criteria pollutant emissions from construction vehicle activity. Fuel consumption from route-specific construction vehicle use is assumed to be:

Caliente/Las Vegas route:	5.5 million liters (1.5 million gallons) diesel fuel, 110,000 liters (29,000 gallons) gasoline over 46 months
Sloan/Jean route:	1.7 million liters (450,000 gallons) diesel fuel, 29,000 liters (7,700 gallons) gasoline over 48 months
Apex/Dry Lake route:	1.6 million liters (420,000 gallons) diesel fuel, 25,000 liters (7,400 gallons) gasoline over 28 months

Accelerated Northern Beltway:	1.9 million liters (500,000 gallons) diesel fuel, 35,000 liters (9,200 gallons) gasoline over 28 months (add these emissions to Caliente/Las Vegas and Apex/Dry Lake results)
Accelerated Southern and Western Beltway:	3.9 million liters (1 million gallons) diesel fuel, 72,000 liters (19,000 gallons) gasoline over 48 months (add these emissions to Sloan/Jean results)

However, activities at any location would generate transient emissions that would be spread over a very large area because construction would be a moving source along various portions of the route. Construction activities in or near the nonattainment area would include intermodal transfer facility construction at Sloan/Jean and Apex/Dry Lake; highway upgrade activities for the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake routes; and accelerated Las Vegas Beltway construction.

Intermodal Transfer Station Construction. Construction of an intermodal transfer station would also generate emissions of criteria pollutants from fuel use and earthmoving activities. Each heavy-haul truck route would require the construction of such a facility. The Caliente intermodal transfer station could serve the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas route. The Caliente station would be in an area in attainment of the National Ambient Air Quality Criteria (attainment area) and construction emissions would adhere to the Prevention of Significant Deterioration regulations (40 CFR 52.21). The Sloan/Jean or Apex/Dry Lake station would be in or near the Las Vegas Basin PM_{10} and carbon monoxide nonattainment area. New stationary emission sources in nonattainment areas are regulated under the General Conformity Rule (40 CFR 93.153).

Table 6-83 lists estimated annual emissions from the construction of an intermodal transfer station. These estimates would apply to each of the three potential site areas. Building an intermodal transfer station would disturb about 0.2 square kilometer (50 acres) over 18 months. Construction of the station would require about 130,000 liters (34,000 gallons) of diesel fuel and about 2,600 liters (690 gallons) of gasoline. The analysis used the method described above for highway construction and upgrades to estimate emissions from earthmoving and fuel use.

Table 6-83. Annual criteria pollutant releases from construction of an intermodal transfer station (kilograms per year).[a]

Pollutant	Construction emission (annual)	PSD limit[b]	Percent of limit[b]	GCR[c] emission threshold	Percent of GCR emission threshold
Nitrogen dioxide	3,400	230,000	1.4	NA[d]	NA
Sulfur dioxide	320	230,000	0.14	NA	NA
Carbon monoxide	2,100	230,000	0.91	91,000	2.3
PM_{10}	9,400	230,000	4.1	64,000 (serious)	15

a. To convert kilograms to tons, multiply by 0.0011023.
b. Prevention of Significant Deterioration (40 CFR 52.21).
c. GCR = General Conformity Rule (40 CFR 93). Applies for releases of pollutants in areas in nonattainment.
d. NA = not applicable.

Table 6-83 lists the percentage of each pollutant in relation to the Prevention of Significant Deterioration limit and the General Conformity Rule emission threshold. The estimated annual releases from the construction of the intermodal transfer station would be almost 4 percent of the Prevention of Significant Deterioration limit and 15 percent of the General Conformity Rule emission threshold (see 40 CFR 93) for PM_{10} and 2.3 percent for carbon monoxide. Construction activities in the Las Vegas nonattainment area would have to follow more stringent fugitive dust (PM_{10}) control measures described in the Clark County PM_{10} State Implementation Plan (DIRS 155557-Clark County 2001, all).

Heavy-Haul Truck and Intermodal Transfer Station Operations. Operations at the intermodal transfer station would include locomotive and heavy-haul truck emissions. Fuel use by heavy-haul trucks would result in emissions of carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM_{10}. Based on the Federal standards for switch locomotives (40 CFR 92.006), there are no emission standards for sulfur dioxide. The locomotive would operate about 30 hours per week at the intermodal transfer station. The pollutant concentration in the area around the route would increase slightly during the passage of the heavy-haul trucks but would not exceed the General Conformity thresholds. About 11 heavy-haul trucks per week would travel to and from the intermodal transfer station.

Table 6-84 lists estimated annual emissions from the operation of an intermodal transfer station. These estimates would apply to each location.

Table 6-84. Annual emissions of criteria pollutants from operation of an intermodal transfer station over 24 years (kilograms per year).[a]

Pollutant	Operation[b] emissions (annual)	PSD limit[c]	Percent of PSD limit	GCR[d] emission threshold	Percent of GCR emission threshold
Nitrogen dioxide	38,000	230,000	17	NA[e]	NA
Sulfur dioxide	(f)	230,000	(f)	NA	NA
Carbon monoxide	11,000	230,000	4.8	91,000	12
Particulate matter (PM_{10})	1,100	230,000	0.48	64,000	1.7

a. To convert kilograms to tons, multiply by 0.0011023.
b. Operations emissions from a switchyard locomotive and heavy-haul trucks.
c. PSD limit = Prevention of Significant Deterioration definition of a major stationary source (40 CFR 52.21); applies for releases of criteria pollutants during operation.
d. GCR = General Conformity Rule (40 CFR Part 93); applies for releases of pollutants in areas in nonattainment.
e. NA = not applicable.
f. 40 CFR 92.006 does not define sulfur dioxide emission standards for locomotives.

The estimated annual releases for the operation of the intermodal transfer station would be about 17 percent or less of the definition of a major stationary source (see Chapter 3, Section 3.1.2.1, or 40 CFR 52.21). The operation of a midroute stopover would result only in small releases of pollutants.

The operation of a yard locomotive would not emit ozone directly, but would emit ozone precursors (nitrogen dioxide and hydrocarbons). The estimated annual releases of the ozone precursors would be small; nitrogen dioxide would be about 17 percent of a major stationary source. Therefore, DOE does not expect the operation of the intermodal transfer facility to be a significant source of ozone.

Because the shipping casks would not be opened, there would be no radiological air quality impacts from normal operations at an intermodal transfer station.

Other air quality impacts would differ among the implementing alternatives (see Section 6.3.3.2).

6.3.3.1.3 *Common Route Hydrology Impacts*

This section describes impacts common to the five heavy-haul truck implementing alternatives (including upgrades to Nevada highways and construction of a midroute stopover and an intermodal transfer station at one of three locations) for surface water and groundwater.

Surface Water

Highway Construction and Upgrades. For road improvement work and construction of a midroute stopover, a contractor could place fuel tank trucks or trailers along the route to support equipment operations. Such a practice would present some potential for spills and releases. As long as the contractor met the regulatory requirements for reporting and remediating spills and properly disposing of or recycling used materials, the probability of unrecovered spills due to negligence or improper work practices would be low. If a release occurred, the potential for chemical contaminants (principally petroleum products) to enter flowing surface water before cleanup would be the largest risk. Surface-water resources along routes for heavy-haul trucks and in the vicinity of intermodal transfer station sites are identified in Chapter 3, Section 3.2.2.2.3. Among all the routes and station sites, three identified surface-water resources cross or run immediately adjacent to a route and two others are as close as 10 to 30 meters (30 to 100 feet). Otherwise, all of the identified surface-water resources are at least 100 meters (330 feet) from the existing roads or intermodal transfer station sites. Two of the station sites and their associated routes for heavy-haul trucks (Sloan/Jean and Apex/Dry Lake) have no identified surface-water resources within 1 kilometer (0.6 mile). The potential for released contaminants to reach flowing surface water would be very low.

A portable asphalt plant to support roadway improvement work would be located along the paving area. Aggregate crushing plants would be located in borrow areas. DOE assumes that the borrow areas would be those normally used by the Nevada Department of Transportation. Spills and releases of asphalt materials, which are predominantly petroleum products but include chemical additives, could occur in the course of operating an asphalt plant. Spill reporting and remediation requirements would be in place for these operations, as described above. Once asphalt was in place, it would be susceptible to minor leaching or bleeding while it cured, similar to the leaching or bleeding that occurs during road construction for other highway projects.

Intermodal Transfer Station Construction. Potential impacts to surface water would include (1) the possible spread of contamination by precipitation, intermittent runoff events, or, where present, releases to flowing water in the single perennial stream, and (2) the alteration of natural drainage patterns or runoff rates that could affect downgradient resources.

Materials that could contaminate surface water would be present during construction; these would consist primarily of petroleum products (fuels and lubricants) and coolants (antifreeze) to support equipment operations. There would not be much bulk storage of these materials. Fuel for vehicles would be purchased from nearby commercial vendors. Minor amounts of building materials such as paints, solvents, and thinners could be present during construction.

The construction of an intermodal transfer station would include stormwater runoff control, as necessary; the completed station would have a stormwater detention basin. These measures would minimize the potential for contaminated runoff to reach a stream.

Appendix L contains a floodplain/wetlands assessment that examines the effects of highway route construction, operation, and maintenance (see Section L.4.1) on the following floodplains in the vicinity of Yucca Mountain: Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash. There are no delineated wetlands at Yucca Mountain.

The assessment in Appendix L compares what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.6, L.3.2.7, L.3.2.8, and L.4.2.2). In general, wetlands have not been delineated at the three sites. The Appendix L assessment does not evaluate potential floodplain or wetland effects along routes for heavy-haul trucks because these are existing roads and DOE assumed upgrades would be limited to those construction activities necessary to accommodate the heavy-haul vehicles. If DOE selected heavy-haul trucks to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, it would also select one of five routes (Figure 6-20) and one of three alternative intermodal transfer station sites (Figure 6-21). DOE would then prepare a more detailed floodplain/wetlands assessment of the selected alternatives to determine to what extent the routes and station locations might be subject to flooding and whether the upgrades would affect wetlands.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Surface-water impacts during operations would be limited to those from maintaining and resurfacing highways and parking areas at a midroute stopover that the heavy-haul trucks would use. As discussed above, good construction practices overseen by the Nevada Department of Transportation would limit impacts that could result from spills of chemical contaminants in the course of highway maintenance and resurfacing activities. Contamination of surface water caused by contaminants leached from new asphalt would be similar to that which occurs in the periodic resurfacing of asphalt highways.

Operations at a completed intermodal transfer station would have little impact on surface waters beyond any permanent drainage alterations that occurred during construction. The station area runoff rates would differ from those of the natural or existing terrain but, given the relatively small size [0.2 square kilometer (50 acres)] of the potentially affected area, they would add little to overall runoff quantities for the area.

The general design criteria for a station would consider the potential for a 100-year flood. Because the spent nuclear fuel and high-level radioactive waste shipping casks would not be opened or otherwise disassembled, the use of industrial design standards for this facility would be appropriate. The analysis assumes that the station would have a diesel-powered generator to provide standby electric power and an associated diesel storage tank. The diesel tank would present a minor potential for spills and releases. Runoff retention areas would limit impacts of potential oil and diesel spills in parking areas.

6.3.3.1.4 *Common Route Groundwater Impacts*

Highway Construction and Upgrades. For highway upgrades, the most likely impacts would be changes to infiltration rates and new sources of contamination that could migrate to groundwater during construction. In this case, however, the potential for impacts would be small due to the relatively small areas affected by upgrading and the fact that highway construction [with the exception of 2 kilometers (1.2 miles) of new highway near Beatty, Nevada, and a midroute stopover], would be a modification of existing roadways. In addition, there would be no large sources of contamination.

Construction activities would disturb and loosen the ground, which could produce greater infiltration rates. However, this impact would be minor and short-lived as contractors completed their work and stabilized the disturbed areas.

Intermodal Transfer Station Construction. Construction activities for an intermodal transfer station would disturb and loosen the ground for some time, which could cause higher infiltration rates. However, this impact would be minor and short-lived as contractors completed the facility and stabilized the disturbed areas.

Water needs for construction would be met by trucking water to the site, installing a well (which would also be used for operations), or possibly by connection to a local water distribution system. In any case, water demand would be small for construction.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The use of highways by heavy-haul trucks would have little impact on groundwater resources. There would be no continued need for water along the route, and there would be no changes to recharge beyond those at the completion of construction.

The operation of a completed midroute stopover and an intermodal transfer station would have little impact on groundwater. Infiltration rates would be as described above for the completion of construction;

the relatively small size of the facilities would minimize changes. Potential sources of contamination at the intermodal transfer station would consist primarily of a diesel fuel tank for the standby generator and heavy equipment. Water demand at the station and the midroute stopover would be small, consisting primarily of the needs of the operators, and would be obtained by the methods described above for construction. This demand would cause no noticeable change in water consumption rates for the area.

Other impacts to hydrology would differ among the implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.5 *Common Route Biological Resources and Soils Impacts*

Highway Construction and Upgrades. Highway upgrade activities would involve improving existing road surfaces and possibly building a bridge near Beatty, Nevada (Caliente route), a midroute stopover (Caliente routes), and about 2 kilometers (1.2 miles) of new highway to handle heavier vehicles (DIRS 155347-CRWMS M&O 1999, Request #048). Areas disturbed by these activities would be in, adjacent to, or near existing rights-of-way. These areas would consist of habitats previously degraded by human activities, which would limit impacts associated with the routes. Clearing of vegetation and soil disturbance would create habitat for colonization by exotic plant species that are present along the candidate routes. This could result in an increase in abundance of exotic species along the routes, which could result in suppression of native species and increased fuel loads for fire. Reclamation of disturbed areas would enhance the recovery of native vegetation and reduce colonization by exotic species. Slight alterations of habitat immediately adjacent to existing roads would have only small impacts on desert tortoises because work would occur in the existing right-of-way. Tortoise populations are depleted for more than a kilometer on either side of roads having average daily traffic greater than 180 vehicles (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). Game species, wild horses and burros, and other animals could temporarily avoid habitat adjacent to roads during highway upgrades, but upgrades would not otherwise add to the effects of these roads on the movement patterns or behavior of these animals. The modification of bridges and culverts over perennial streams, if necessary, could temporarily disrupt stream flow and increase sedimentation in downstream aquatic environments. DOE anticipates that preconstruction surveys of potentially disturbed areas would identify and locate sensitive biological resources and best management practices would minimize the impacts of highway upgrades.

All of the heavy-haul truck implementing alternatives cross perennial or ephemeral streams that may be classified as jurisdictional waters of the Unites States. Discharge of dredged or fill material into those waters is regulated under Section 404 of the Clean Water Act. After the selection of a heavy-haul truck implementing alternative, if requested, DOE would assist the Nevada Department of Transportation to identify any jurisdictional waters of the United States that highway upgrades would affect; develop a plan to avoid when possible, and otherwise minimize, impacts to those waters; and obtain, as appropriate, an individual or regional permit from the U.S. Army Corps of Engineers for the discharge of dredged or fill material. By implementing the mitigation plan and complying with other permit requirements, the Nevada Department of Transportation would ensure that impacts to wetlands and other waters of the United States would be small.

The primary soil impacts from improvements to highways would be land disturbance. Road improvements would consist of widening existing roadways, constructing turnouts and truck lanes at designated stretches along the routes, and improving existing intersections. Water would be applied during construction to suppress dust and compact the soil; this would reduce the potential for erosion. Drainage control along the route probably would remain as it is now. These combined measures would minimize the potential for adverse impacts to soils.

Intermodal Transfer Station Construction. The biological settings of the three potential sites for an intermodal transfer station differ; Section 6.3.3.2 addresses impacts for each of the Nevada heavy-haul transportation implementing alternatives.

Soil impacts from the construction of an intermodal transfer station would arise primarily from the direct impacts of land disturbance and would apply to each station site and route. Chapter 3, Section 3.2.2.2.1, lists estimates of land area required for an intermodal transfer station. The disturbed areas probably would be subject to increased erosion for at least some of the construction phase. Water would be applied during construction to suppress dust and compact the soil; this would reduce the potential for erosion. At the beginning of station construction, the topsoil would be stripped and stockpiled; during construction, temporary erosion control systems would minimize erosion impacts. At the completion of construction, the topsoil would be replaced over areas not used for station facilities, the area disturbed surrounding the station would be revegetated, and other permanent erosion control systems would be installed as appropriate.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Impacts to biological resources from operations along any of the five possible routes would be very small. Because existing roadways would not be greatly altered, operations and maintenance would not lead to additional habitat losses. Heavy-haul truck operations could kill individuals of some species, but losses would be unlikely to have a detectable impacts on the regional population of any species and would be small in comparison to losses caused due to other traffic on the highways. Passing trucks could disrupt wildlife, but such effects would be transitory. The use of an upgraded highway would have only a small impact on soils.

Impacts to biological resources from operations at an intermodal transfer station and a midroute stopover would be very small. Operations would not lead to additional habitat losses. Individuals of some species could be disturbed or killed by human activities at the station and stopover, but such losses would be unlikely to have a detectable impact on the regional population of any species.

The use of a completed intermodal transfer station and midroute stopover should have only small impacts on soils. The station and stopover would be maintained throughout the operations period, including the repair of erosion damage to the grounds around the station and the rail siding.

Other impacts to biological resources would differ among the heavy-haul truck implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.6 *Common Route Cultural Resources Impacts*

Highway Construction and Upgrades and Intermodal Transfer Station Construction. Impacts (such as disturbing sites or damaging artifacts) could occur, primarily from surface-disturbing activities, to archaeological, historic, and traditional Native American cultural sites from upgrading highways, constructing a midroute stopover, and building an intermodal transfer station. Cultural resource inventories by the Nevada Department of Transportation and others identify certain archaeological and historic sites in established rights-of-way [generally about 60 meters (200 feet) wide]. Section 6.3.3.2 discusses the impacts of individual routes.

Heavy-Haul Truck and Intermodal Transfer Station Operations. After the identification, evaluation, and mitigation of impacts to significant cultural sites prior to construction activities associated with the upgrading of highways or construction of an intermodal transfer station, there would be no additional impacts to these resources from the operation of a heavy-haul truck route.

Although existing highways would be used, American Indians have expressed concern about the transport of spent nuclear fuel and high-level radioactive waste through tribal lands and through the larger region that comprises their traditional holy lands (DIRS 102043-AIWS 1998, all). Use of the Caliente/Las Vegas, Apex/Dry Lake, or Sloan/Jean route would include travel on U.S. 95 across a 1.6-kilometer (1-mile) section of the Las Vegas Paiute Indian Reservation. The Caliente/Las Vegas and Apex/Dry Lake routes pass near the Moapa Indian Reservation. The Caliente route along U.S. Highway 95 runs adjacent to the Scottys Junction trust lands parcel that Congress recently transferred to the Timbisha Shoshone tribe.

Other impacts to cultural resources would differ among the heavy-haul truck implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.7 *Common Route Occupational and Public Health and Safety Impacts*

Highway Construction and Upgrades. Traffic-related fatalities could occur among workers and members of the public during the upgrading of Nevada highways for heavy-haul truck use. The number of fatalities would depend on the amount of construction activity needed to upgrade a route. There would be no other common impacts for highway construction under any of the implementing alternatives. Section 6.3.3.2 describes impacts for each of the implementing alternatives. The construction of a midroute stopover for routes originating in Caliente would not add much to the impacts of highway construction discussed in Section 6.3.3.2.

Intermodal Transfer Station Construction. Impacts to workers from industrial hazards during the construction of an intermodal transfer station would be the same for all three possible locations. These impacts would be small (see Table 6-85). The analysis estimated impacts to workers in terms of total recordable cases of injury or illness, lost workday cases, and fatalities to workers. In addition, it estimated that there would be less than 1 (0.03) construction and construction workforce traffic-related fatality.

Table 6-85. Health impacts to workers from industrial hazards during construction of an intermodal transfer station.

Group	Total recordable cases[a]	Lost workday cases	Fatalities
Involved	3.8	1.8	0.01
Noninvolved[b]	0.3	0.1	0
Totals[c]	4.1	1.9	0.01

a. Total recordable cases includes injuries and illness.
b. Noninvolved worker impacts based on 25 percent of the involved worker level of effort.
c. Impacts are totals for 18 months.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Section 6.3.3.2 discusses impacts for heavy-haul truck transportation and operations for each of the heavy-haul truck implementing alternatives. Common impacts for intermodal transfer station operations would include those to workers from industrial hazards and exposure to ionizing radiation (radiological impacts). DOE has determined that, because worker exposures to hazardous or toxic materials would be unlikely, workers at the station would incur no impacts from such materials. Table 6-86 lists potential impacts to workers from industrial hazards. In addition, there would be less than one (0.38) traffic-related fatality involving intermodal transfer station workers during operations.

Table 6-86. Health impacts to workers from industrial hazards during operation of an intermodal transfer station.

Group	Total recordable cases[a]	Lost workday cases	Fatalities
Involved	52	29	0.14
Noninvolved[b]	3.0	1.1	0.003
Totals[c]	55	30	0.15

a. Total recordable cases includes injuries and illness.
b. Noninvolved worker impacts based on 25 percent of the involved worker level of effort.
c. Totals for 24 years of operations.

Intermodal transfer station workers would be exposed to direct radiation from the shipping casks the station would handle. Involved worker exposures would occur during both the inbound (to the proposed repository) and outbound (to the commercial and DOE sites) portions of the shipment campaign. The involved worker group would include as many as 20 personnel performing station operational tasks over a total shipment campaign of about 19,300 casks (9,650 inbound and 9,650 outbound).

The analysis assumed that noninvolved workers would not be exposed to direct radiation during intermodal transfer station operations. To assess potential radiological impacts at the intermodal transfer stations, the EIS analysis assumed that noninvolved workers would be persons involved with the day-to-day operations of the facility and would have no direct involvement with handling spent nuclear fuel and high-level radioactive waste.

Table 6-87 lists doses and radiological impacts to an individual worker and the involved worker population. The estimated doses are based on involved worker doses from DIRS 104791-DOE (1992, p. 4.2).

Table 6-87. Doses and radiological impacts to involved workers from intermodal transfer station operations.[a]

Group	Dose	Latent cancer fatality
Maximum individual worker	12 rem[b]	0.005[c]
Involved worker population	260 person-rem	0.11[d]

a. Totals for 24 years of operations.
b. Based on 500-millirem-per-year administrative dose limit.
c. The estimated probability of a latent cancer fatality in an exposed individual.
d. The estimated number of latent cancer fatalities in an exposed involved worker population.

Table 6-87 indicates that the involved group of workers could incur a collective dose of about 260 person-rem over the operating period of the intermodal transfer station. The analysis estimated that about 0.1 latent cancer fatality would occur in the exposed worker population. The maximum individual dose accumulated by these workers was assumed to be 500 millirem per year or 12 rem for a worker who worked at the facility for the 24-year operating period. This dose would result in a 0.005 probability of a latent cancer fatality (about a 1-in-200 chance). The assumed annual average dose to an involved worker is the administrative limit on occupational dose that DOE established for its facilities (DIRS 156764-DOE 1999, Article 211). Because vehicles would not be loaded or unloaded at a midroute stopover (Caliente routes), workers at the stopover would receive only small radiation doses.

Incident-Free Transportation. Incident-free impacts of heavy-haul truck transportation in Nevada to individual workers and the public would be unique for each of the five Nevada heavy-haul truck transportation implementing alternatives; these are discussed for each implementing alternative in Section 6.3.3.2. In addition, the incident-free impacts that would occur in Nevada from 1,079 legal-weight truck shipments, although common among the heavy-haul truck implementing alternatives, are reported along with the incident-free impacts for heavy-haul truck transportation in Section 6.3.3.2 for each heavy-haul truck implementing alternative.

Incident-free impacts to hypothetical maximally exposed individuals would be similar among the Nevada heavy-haul truck transportation implementing alternatives. Table 6-88 lists the impacts to maximally exposed individuals including a Nevada-specific individual exposed to heavy-haul truck shipments. Appendix J, Section J.1.3.2.2 describes assumptions for estimating doses to maximally exposed individuals along routes in Nevada.

Accidents. Accident risks and maximum reasonably foreseeable accidents for heavy-haul truck shipments of spent nuclear fuel and high-level radioactive waste would be similar among the Nevada heavy-haul truck transportation implementing alternatives, so this section discusses them.

Table 6-89 lists the accident risks from the transportation of spent nuclear fuel and high-level radioactive waste for the five Nevada heavy-haul truck transportation implementing alternatives. The data show that

Table 6-88. Estimated doses and radiological impacts to a maximally exposed individual for heavy-haul truck implementing alternatives.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (rail, heavy-haul truck or legal-weight truck)	48[c]	0.02
Inspector	34	0.013
Railyard crew member	4.2	0.002
Public		
Resident along route (rail)	0.002	0.000001
Nevada resident along route (heavy-haul)[d]	0.53	0.00027
Person in traffic jam[e] (legal-weight truck)	0.02	0.000008
Person at service station[f] (legal-weight truck)	0.08	0.00004
Resident near rail stop[g]	0.002	0.000001

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operations.
c. Based on 2-rem-per-year administrative dose limit. If a lower dose limit, for example 500 millirem per year, was imposed for transportation workers or state inspectors, maximally exposed individual doses would be lower. See DIRS 156764-DOE (1999, Article 211) for DOE guidance on occupational dose limits.
d. This represents a Nevada resident approximately 15 meters (49 feet) from an intersection. This individual would be exposed for 1 minute per shipment plus 30 minutes per year due to traffic delays.
e. Person in a traffic jam is assumed to be exposed one time only.
f. Assumes the person works at the service station for all 24 years of operations. Mitigation would be required to reduce doses to members of the public to below 100 millirem per year.
g. This represents a Nevada resident approximately 30 meters (98 feet) from the branch rail line. See Section J.1.3.2.2.

Table 6-89. Health impacts[a] to the public from accidents for Nevada heavy-haul truck implementing alternatives.

Risk	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Apex/Dry Lake	Sloan/Jean
Radiological accident risk					
Dose risk (person-rem)	0.01	0.0019	0.056	0.056	0.12
LCF[b]	0.000005	0.000001	0.0000009	0.000028	0.00006
Traffic fatalities	0.6	0.33	0.43	0.23	0.25

a. Impacts are reported for 24 years of operations.
b. LCF = latent cancer fatality.

the risks, which are for 24 years of operations, are low for all five alternatives. These risks include those associated with transporting 1,079 legal-weight truck shipments from the commercial sites that would not have the capability to load rail casks while operational. Small variations in the risk values, principally evident for a Sloan/Jean route, are in part a result of the risks associated with transporting rail casks arriving from the east on the Union Pacific Railroad's mainline through the Las Vegas metropolitan area to a Sloan/Jean intermodal transfer station. The values that would apply for a Caliente/Chalk Mountain or Apex/Dry Lake route are lower because of a shorter route (Apex/Dry Lake), or a more remote and mid-length route (Caliente/Chalk Mountain).

Consequences of Maximum Reasonably Foreseeable Accident Scenarios. DOE evaluated the impacts of maximum reasonably foreseeable accident scenarios for national transportation (see Section 6.2). The results for the national transportation mostly rail scenario apply to transportation in Nevada.

6.3.3.1.8 *Common Route Socioeconomic Impacts*

DOE analyzed five Nevada heavy-haul truck transportation implementing alternatives for potential socioeconomic impacts from expenditures to upgrade and maintain Nevada highways, operate heavy-haul trucks, and construct and operate an intermodal transfer station.

Highway Construction and Upgrades. The dynamics of specific construction projects include a period of brief, intense elevation in project-related employment, followed by an abrupt decrease in associated employment opportunities as construction workers move on to other projects. Project dynamics can also include population increases followed by net declines in population as related employment requirements diminish. In general, increases in population lag behind increases in employment. For the most part, the projected impacts of highway upgrade work would occur in Clark County, which the analysis assumed would be the home county for construction workers because of its large workforce. Section 6.3.3.2 discusses the analysis of impacts to counties along each of the five candidate routes. The time and employment required to complete road upgrades would depend on the route.

Intermodal Transfer Station Construction. If a decision was made to construct an intermodal transfer station, DOE anticipates that preliminary architecture and engineering work would begin in 2007, followed by the start of construction at the selected site in 2008. Construction would last about 18 months. For this analysis, DOE assumed that construction workers would probably come from Clark County.

Although there would be small differences among the three candidate locations for an intermodal transfer station, the total statewide increase in employment (direct and indirect) that would result from the project would peak in 2008 and would be about 135 workers. Population increases resulting from a net influx of new workers would peak in 2009 with about 65 additional residents. These employment and population increases, which would occur mostly in Clark County, would be small and temporary for the affected counties.

Increases in real disposable income from constructing an intermodal transfer station would peak in 2008 at between about \$3.6 million and \$4.1 million. The increase in Gross Regional Product would also peak in 2008 at between \$10.8 million and \$11.4 million. State and local government expenditures would peak in 2009 between \$198,000 and \$243,000. These increases to real disposable income, Gross Regional Product, and government expenditures from construction would be short-term and less than 0.5 percent of the baselines in the affected counties. (All dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Highway Maintenance for Heavy-Haul Truck Operations. If DOE decided to use heavy-haul trucks, annual maintenance would be required after the completion of the highway upgrades. In addition, DOE assumed the routes would be resurfaced approximately every 8 years. Thus, highway expenditures for resurfacing a selected route would occur in approximately 2016, 2024, and 2032. The employment required for road maintenance would depend on the selected route. Section 6.3.3.2 discusses route-specific impacts for each of the five candidate routes.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The socioeconomic impacts of operating heavy-haul trucks and an intermodal transfer station largely would occur in the county in which the station was located. Section 6.3.3.2 discusses these impacts for each of the five candidate routes.

6.3.3.1.9 *Common Route Noise and Vibration Impacts*

Highway Construction and Upgrades and Intermodal Transfer Station Construction. Impacts would occur from construction noise associated with upgrading road surfaces, constructing a midroute stopover, and constructing an intermodal transfer station. The upgrades and construction would include the use of earth-moving equipment (bulldozers, graders, loaders, dump trucks) and asphalt-laying equipment. Earthmoving equipment would dominate maximum noise levels from construction and would achieve levels of 70 to 80 dBA at 15 meters (50 feet) from the source. The potential for noise impacts from construction would depend on the presence of humans along the routes and near the intermodal transfer station location. These persons would live in communities and possibly individual residences. Noise impacts from road upgrades and general construction would be transient, move with the construction, and end when the construction ended. The impacts, therefore, would be temporary for any location along affected highways. Construction noise, which would not occur at night, would be equivalent to the daytime standard (60 dBA) at distances of about 2,000 meters (6,600 feet). Construction upgrades of heavy-haul truck routes and construction of branch rail lines would be unlikely to cause vibration damage to historic buildings because of the distance of potentially sensitive buildings from construction sites.

The American Indian Writers Subgroup (DIRS 102043-AIWS 1998, p. 2-19) has identified noise generated along transportation routes as a concern because it could affect ceremonies and the solitude necessary for healing and praying. Areas or sites of interest to Native Americans have not been identified along these routes.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Heavy-haul trucks would be double-tractor vehicles that this analysis assumed would travel at speeds of 32 to 80 kilometers (20 to 50 miles) an hour. Noise levels probably would be greatest when loaded heavy-haul trucks were moving up grades at speeds as slow as 8 kilometers (5 miles) an hour. This would occur as the trucks approached the proposed repository site and on portions of the Caliente route (see Chapter 2, Section 2.1.3.3). At 48 kilometers (30 miles) an hour, the estimated noise from a single heavy-haul truck moving up a 5-percent grade would be 45 dBA at a distance of 630 meters (about 2,100 feet) from the road with no background traffic. Elevated truck noise would not be a consideration on the Nevada Test Site, the Nellis Air Force Range, or the repository site. Transportation workers would use hearing protection as required by Occupational Safety and Health Administration regulations.

To assess the impact noise generated by heavy-haul trucks, DOE based the estimated increase in the 1-hour average sound level on traffic volumes along the routes for heavy-haul trucks (DIRS 156930-NDOT 2001, all). Noise estimates were based on a total of three double-tractor vehicles passing through a community or past a given point on a highway within 1 hour (DIRS 155778-Melnick 1998, all). The estimated increase in the 1-hour average sound level would not be perceptible in areas with high traffic volume and would be as high as 0.3 to 4.7 dBA in areas of low traffic volume. The estimated noise levels in this analysis were dominated by commercial tractor-trailers (20 percent of total traffic volume) on the open highway and in smaller communities.

During operations, DOE would transport 11 shipments a week of spent nuclear fuel and high-level radioactive waste to the proposed repository and 11 empty casks from the repository. Because the heavy-haul trucks probably would travel individually, elevated noise would occur during the brief time when a vehicle passed through communities. There would be no nighttime noise because trucks of this size would be restricted to operating during daylight hours. Truck noise at a midroute stopover would be similar to noise along the adjacent route. Therefore, the potential for adverse noise impacts from heavy-haul trucks would be low.

Noise associated with operations at an intermodal transfer station would occur as it received shipments and transferred them from railcars to heavy-haul trucks for transport to the proposed repository site. However, the baseline noise level is already elevated because of existing rail line operations at the potential station locations. Additional sources of noise at a station would include transferring railcars from trains into the station, moving the railcars in the station, and receiving returning empty transportation casks. Railcars could come to the station at night, so there would be a potential for nighttime sources of noise. However, shipments in the station could be handled during daylight hours, minimizing the potential for noise impacts.

Ground vibration resulting from the operation of heavy-haul trucks or trains would be unlikely to produce vibration levels of a magnitude sufficient to cause building damage. Heavy-haul trucks can create potentially damaging vibration if the vehicle hits a bump or pothole in the road. The magnitude of vibration produced depends on the speed of the vehicle and the size of the bump. Most of the energy of impact is absorbed by the inflated tires; as a consequence, ground vibration would not be a major impact for these operations. Heavy-haul trucks would operate at reduced speeds when operated at intermodal transfer stations. There are no known historic buildings or ruins of cultural significance that ground vibration could affect near intermodal transfer stations.

Other noise impacts would differ among the implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.10 *Common Route Aesthetics Impacts*

Highway Construction and Upgrades and Intermodal Transfer Station Construction. There could be impacts on visual resources during these activities because of the presence of workers, camps, vehicles, large earth-moving equipment, laydown yards, large cranes, and dust generation. However, this phase would be of limited duration (approximately 18 months for an intermodal transfer station and as long as 46 months for highway improvements). An intermodal transfer station would be in an already developed area, either for industrial or commercial use or adjacent to existing roads or rail corridors. Therefore, the facility would not change the character of land use in its vicinity. Dust generation during construction would be controlled by implementing best management practices such as misting or spraying disturbed areas. Construction activities would conform with the Bureau of Land Management Visual Resources Management guidelines (DIRS 101505-BLM 1986, all). If a route crosses Class II lands, more stringent management requirements would be necessary to retain the existing character of the landscape. However, the short duration of highway modification or construction activities, combined with the use of best management practices, would mitigate the impacts of activities, which could exceed the management requirements on any Class II lands.

Heavy-Haul Truck and Intermodal Transfer Station Operations. As many as 22 shipments would leave or arrive at the intermodal transfer station each week. Visual impacts would result from the presence of the station, increased worker activity in the area, the arrival and departure of trains, loading and unloading operations, and the arrival and departure of heavy-haul trucks. Noise and lighting impacts would occur at an intermodal transfer station but, due to the remote locations, there would be no significant impacts. Impacts would not exceed Bureau of Land Management Visual Resource Management Class III objectives, which require only the partial retention of the existing character of the landscape.

Other aesthetic impacts would differ among the implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.11 *Common Route Utilities, Energy, and Materials Impacts*

Highway Construction and Upgrades. The amounts of utilities, energy, and materials needed would depend on the amount of upgrading to be done, which would be specific to each route. The amount of utilities, energy, and materials for each route is given in the following sections. All of the required amounts are much less than current use rates in Nevada. For example, fossil-fuel consumption in Nevada was about 3.8 billion liters (1 billion gallons) in 1996 and none of the routes would require more than 0.5 percent of the annual consumption (DIRS 148094-BTS 1997, all).

Intermodal Transfer Station Construction. Intermodal transfer station design would be the same for any of the three sites and would include a small railyard with several sidings, a 180-metric-ton (200-ton) bridge crane, two steel prefabricated buildings (one for administration and one for maintenance), and a large paved area for heavy-haul truck parking and maneuvering. The basic facility would be a light industrial site with moderate utility requirements. During construction the electrical requirements would be supplied by portable generating equipment. Table 6-90 lists the materials that would be consumed during construction. The quantities of concrete, asphalt, and steel listed in the table are not substantial in comparison to annual use rates and would not affect the regional supply system. For example, the concrete required for an intermodal transfer station would be less than 1 percent of the concrete used in Nevada in 1998 (DIRS 104926-Bauhaus 1998, all). Similarly, the demand for electricity and fossil fuel during construction would not be great. The construction of a midroute stopover for heavy-haul trucks (routes originating in Caliente) is accounted for in the specific route data included in the following sections.

Table 6-90. Construction utilities, energy, and materials for an intermodal transfer station.

Electrical demand (kilowatts)	Fossil fuel (liters)[a]	Concrete (thousand metric tons)[b]	Asphalt (thousand metric tons)	Steel (thousand metric tons)
Onsite generation	Small	7.9	16	1.4

a. To convert liters to gallons, multiply by 0.26418.
b. To convert metric tons to tons, multiply by 1.1023.

Highway Maintenance for Heavy-Haul Truck Operations. Highways used by heavy-haul trucks would be maintained annually and resurfaced, on average, every 8 years. The amounts of utilities, energy, and materials for the annual and 8-year maintenance activities would be less than the initial amounts for upgrading the highways.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The current estimate of electrical demand during the operation of an intermodal transfer station would be 165 kilowatts (DIRS 155347-CRWMS M&O 1999, Request #38). This would include 30 kilowatts for lighting, 50 kilowatts for each of the two buildings, 5 kilowatts for the guard station, and 30 kilowatts for the crane. The actual rate would be substantially less than peak capacity because operations would be intermittent. Only small amounts of fossil fuel would be used at an intermodal transfer station. Chapter 10 discusses fossil-fuel use for heavy-haul truck operations.

Other impacts on utilities, energy, and materials would differ among the implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.12 *Common Route Waste Management Impacts*

Highway Construction and Upgrades. Highway construction results in minimal waste. Excavated soil is used for fill elsewhere along the route and asphalt is recycled (DIRS 152538-Hoganson 2000, all; DIRS 152535-Hoganson 2000, all). Upgrading highways, including constructing a midroute stopover with a security trailer, could generate waste such as vegetation from land clearing (DIRS 152538-Hoganson 2000, all), construction debris from the trailer setup, and waste from onsite equipment maintenance (DIRS 152537-Hoganson 2000, all) that an independent contractor would dispose of in permitted landfills, or would recycle in the case of lubricants. In addition, construction materials for upgrading engineered structures such as bridges and culverts would be in correct sizes and numbers to minimize waste. Residual materials would be saved for reuse. A commercial vendor would provide portable restroom facilities and would manage the sanitary sewage. Waste would be handled in accordance with applicable environmental, occupational safety, and public health and safety requirements to minimize the possibility of adverse impacts to vegetation, wildlife, soils, surface and groundwater, and air quality from construction inside or outside of the region of influence.

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Intermodal Transfer Station Construction. The administration building would be a prefabricated building and the maintenance building would be built on the site. Construction of the maintenance building would require traditional materials such as steel, lumber, and concrete that would result in debris requiring disposal or recycling. Excess construction materials would be salvaged. A maximum of 23 metric tons (26 tons) of construction debris would be disposed of in a local construction debris landfill. Approximately 750,000 metric tons (820,000 tons) of construction debris was disposed of in Nevada in 2000 (DIRS 155565-NDEP 2001, Section 2.1), so the maintenance building construction would add less than 0.01 percent. In addition, construction could require paints and resins that could become hazardous if discarded. Hazardous waste would be shipped to a permitted treatment and disposal facility. A commercial vendor would provide portable restroom facilities as necessary and manage the resulting sanitary sewage. Waste quantities from construction would be about the same for all sites. Impacts to treatment and disposal capacity from disposing of the construction debris, hazardous waste, and sanitary sewage would be small and consistent for all station locations.

Highway Maintenance for Heavy-Haul Truck Operations. Periodic maintenance of highways and resurfacing every 8 years would be unlikely to generate wastes, and asphalt would be recycled (DIRS 152535-Hoganson 2000, all). Environmental impacts from waste would be unlikely.

Heavy-Haul Truck Operations. Heavy-haul truck operations along any of the four routes would result in similar wastes from vehicle maintenance. Maintenance wastes are included in the intermodal transfer station operation discussion below.

The operation of a midroute stopover would generate sanitary solid waste and sanitary sewage at the security trailer. The waste would be proportional to the number of persons using the facility, about 5 kilograms (11 pounds) per day per person of solid waste (DIRS 155567-NDEP 2001, p. 5) and about 57 liters (15 gallons) of wastewater per day per person (DIRS 152492-Gibson 1974, p. 55) if potable water is supplied or less if chemical toilets are used. DOE would dispose of the sanitary solid waste in a permitted municipal landfill; the sanitary sewage would be trucked to a municipal sewage facility. The small quantities of solid and sanitary wastes would have a very small impact on treatment and disposal capacity. Management and disposition of the wastes from operations would comply with applicable environmental and occupational and public safety regulations to minimize the possibility of adverse impacts to vegetation, wildlife, air quality, soils, and water resources.

Intermodal Transfer Station Operations. Operations, regardless of the location, would generate (1) sanitary solid waste such as waste paper from office and personnel activities, (2) waste from maintenance activities, and (3) potentially a small amount [0.71 cubic meter (25 cubic feet) per month] of low-level radioactive waste such as the smear wipes from radiological surveys of shipping casks and vehicles (DIRS 104849-CRWMS M&O 1997, p. 10). The routine maintenance and minor repair of the estimated 20 tractor-trailers assigned to an intermodal transfer station would generate waste and recyclable materials. Lubricants, lead-acid batteries, tires, fuel, antifreeze, refrigerant, and miscellaneous used parts would be generated (DIRS 152534-Hoganson 2000, all). The majority of these wastes could be recycled, as is the case at another DOE fleet operation facility (DIRS 152532-Hoganson 2000, all). Estimated annual recyclable material would be 5.5 metric tons (6.0 tons), primarily lubricating oil. Waste requiring disposal would consist of 1,400 kilograms (3,000 pounds) of nonrecyclable tires per year and 23 kilograms (50 pounds) of drained oil filters per year (DIRS 152534-Hoganson 2000, all). About 83,000 metric tons (91,000 tons) of this type of waste was disposed of in Nevada in 2000 (DIRS 155565-NDEP 2001, Section 2.1), so the truck maintenance waste would add less than 0.01 percent. In addition, the intermodal transfer station would generate sanitary sewage that would be disposed of in an onsite septic system or through connection to a municipal sewage facility.

The intermodal transfer station operator would dispose of nonhazardous solid waste in a local permitted landfill with available capacity. Hazardous waste such as nonrecyclable lead-acid batteries and low-level radioactive waste, if any, would be shipped to treatment and disposal facilities with appropriate permits. The small quantities would have very little impact on the treatment and disposal facilities. Treatment and disposal capacity for hazardous waste would be above the expected demand until 2013 (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50). Disposal capacity for a broad range of low-level radioactive wastes would be available at two currently licensed facilities (DIRS 152583-NRC 2000, section on U.S. Low-level Radioactive Waste Disposal).

There would be no unique environmental impacts of waste management for any of the heavy-haul truck implementing alternatives. Waste would be managed in accordance with applicable environmental, occupational safety, and public health and safety requirements to minimize the possibility of adverse impacts to vegetation, wildlife, air quality, soils, and water resources. Impacts to the capacity of treatment and disposal facilities receiving wastes generated during Nevada transportation would be small due to the small quantities of waste expected.

6.3.3.2 Impacts Specific to Individual Nevada Heavy-Haul Truck Implementing Alternatives

6.3.3.2.1 *Caliente Route Implementing Alternative*

The Caliente route (Figure 6-22) is approximately 533 kilometers (331 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the intermodal transfer station to U.S. Highway 93. The trucks would travel west on U.S. 93 to State Route 375, then on State Route 375 to the intersection with U.S. 6. The trucks would travel on U.S. 6 to the intersection with U.S. 95 in Tonopah. The trucks would travel into Beatty on U.S. 95 where a short alternative truck route would be built on the west side of town because an existing intersection is too constricted to allow a heavy-haul truck to turn. Heavy-haul vehicles would then travel south on U.S. 95 to Lathrop Wells Road at Amargosa Valley, which would access the Yucca Mountain site.

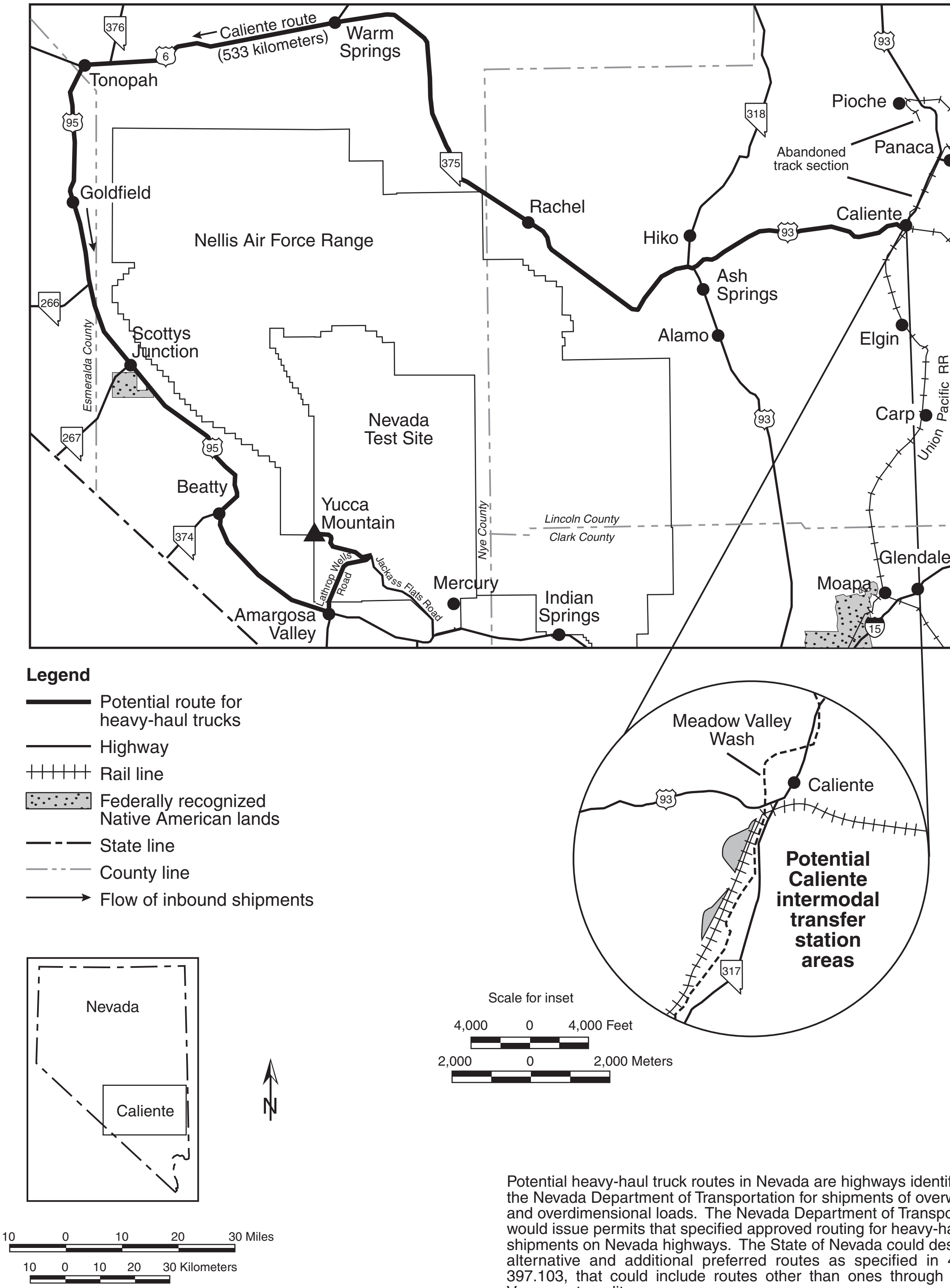
DOE would construct a parking area along a Caliente route to enable heavy-haul vehicles to park overnight. This parking area could be needed because the travel time (vehicle in motion plus periodic short stops for inspections) associated with a Caliente route would be as much as 16 hours and because DOE anticipates that the State of Nevada would issue special travel permits for the trucks that would include time-of-day and day-of-the-week travel restrictions that could preclude completing a trip in 1 day. This parking area would probably be near U.S. 6 between Warm Springs and Tonopah.

The potential siting areas for an intermodal transfer station are south of the City of Caliente in the Meadow Valley Wash area. DOE has identified two areas along the west side of the canyon, with a combined area of 0.74 square kilometer (180 acres). Areas along the east side of the canyon would not be used to avoid disrupting Meadow Valley Wash and because of poor access to the Union Pacific rail line. The estimated life-cycle cost to construct and operate an intermodal transfer station and to operate heavy-haul trucks along the Caliente route would be about $669 million in 2001 dollars.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; and utilities, energy, and materials. Impacts that would occur to air quality and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice concerns in Nevada.

6.3.3.2.1.1 Caliente Route Land Use and Ownership

This section describes land-use impacts that could occur from the construction and operation of a Caliente intermodal transfer station and upgrade of highways and heavy-haul truck operation over the



Potential heavy-haul truck routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative and additional preferred routes as specified in 49 CFR 397.103, that could include routes other than ones through the Las Vegas metropolitan area.

To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104588-YMP (1998, all).

Figure 6-22. Caliente heavy-haul truck route.

Caliente route. Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and associated route.

With the exception of a small portion of the most northern part of the site area for an intermodal transfer station, the area is on patented land owned by the City of Caliente. The remaining part of the northern site is administered by the Bureau of Land Management. The northern site also includes an existing wastewater treatment plant (DIRS 104993-CRWMS M&O 1999, p. 21). A transfer of property from the Bureau, the City of Caliente, or other entities to DOE would be required.

Highway Construction and Upgrades. Land-use impacts that would be common to all locations are discussed in Section 6.3.3.1. The Caliente intermodal transfer station, located near the entrance to Kershaw-Ryan State Park, would be built on lands currently used for industrial or commercial purposes. Because of this, there should be no additional impacts to land use. Park visitors would receive short-term visual impacts from construction activities. In addition, park visitors could be affected by noise from construction activities that could lessen their recreational experience. These short-term impacts would exist only during construction.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 3.4 square kilometers (834 acres) of land would be disturbed by the road upgrades and additional construction activities required for this route. Table 6-91 summarizes these disturbances. Approximately 0.04 square kilometer (10 acres) of land near Beatty, Nevada, would be acquired to construct approximately 2 kilometers (1.2 miles) of new highway. This section of highway would be needed to avoid conflicts between the requirement of wide turning areas for heavy-haul trucks and existing land uses in Beatty where U.S. 95 makes a 90-degree turn. In addition, approximately 0.04 square kilometer (10 acres) of land in the vicinity of Tonopah would be acquired for a midroute stopping area for heavy-haul trucks. This additional land requirement could require the purchase by or transfer of land to DOE.

Table 6-91. Land disturbances along the Caliente heavy-haul truck route.

Disturbance	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	1.9
Aggregate plants	0.3
Road widening	0.7
Passing lanes	0.2
Truck turnouts	0.08
Beatty truck alternate	0.04
Fortymile Wash new road	0.04
Overnight stops	0.04
Total disturbed area	3.4

. Numbers approximate due to rounding.
. To convert square kilometers to acres, multiply by 247.1.

Operations. There would be no direct land-use impacts associated with the operation of the Caliente intermodal transfer station or the Caliente route for heavy-haul trucks other than those described in Section 6.3.3.1.

6.3.3.2.1.2 Caliente Route Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these potential impacts as well as those from the construction and operation of an intermodal transfer station and heavy-haul truck operations over the Caliente route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all of the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that are unique to the Caliente route.

Surface Water

Section 6.3.3.1 discusses impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed apply to surface water along the Caliente route.

Appendix L contains a comparison of what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.6 and L.4.2.2). As noted in Section L.3.2.6, the two locations being considered for the Caliente intermodal transfer station are outside the 100-year flood zone of Meadow Valley Wash, but inside the 500-year flood zone.

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. The upgrades to the Caliente route would require about 126,000 cubic meters (100 acre-feet) (DIRS 104917-LeFever 1998, all) of water which, for planning purposes, was assumed to come from 16 wells.

The average amount of water withdrawn from each well would be about 7,900 cubic meters (6 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies the hydrographic areas over which the Caliente route would pass, their perennial yields, and whether the State considers each a Designated Groundwater Basin. Table 6-92 summarizes the status of the hydrographic areas associated with the Caliente route. It also identifies the approximate portion of the route that would pass over Designated Groundwater Basins.

Table 6-92. Hydrographic areas along Caliente route.

	Designated Groundwater Basins	
Hydrographic areas	Number	Percent of corridor length
19	8	40

The withdrawal of 7,900 cubic meters (6 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-92, about 40 percent of the route's length would be in areas with Designated Groundwater Basins, where the Nevada State Engineer's office carefully watches the potential for groundwater depletion. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Requests for water appropriations under this action would be for minor amounts and for a short-term construction action, which should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck to construction sites (about 7,000 truckloads), or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation would ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses the impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

6.3.3.2.1.3 Caliente Route Biological Resources

Section 6.3.3.1 discusses the impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all candidate sites for an intermodal transfer station and associated routes. This section discusses the construction- and operations-related impacts that would be unique to the Caliente intermodal station and route.

Highway Construction and Upgrades. Potential Caliente intermodal transfer station siting locations include two areas along the west side of the Meadow Valley Wash canyon. The land cover types are agriculture and salt desert scrub (DIRS 104593-CRWMS M&O 1999, pp. 3-30 and D-1). The construction site would disturb approximately 0.2 square kilometer (50 acres). No special status species occur in the proposed location of the Caliente intermodal transfer station. However, two species classified as sensitive by the Bureau of Land Management—the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker—occur in the adjacent Meadow Valley Wash (DIRS 104593-CRWMS M&O 1999, p. K-1). The construction of an intermodal transfer station could affect these fish by increasing the sediment load in the wash during construction. This construction would not affect southwestern willow flycatchers or their habitat in Meadow Valley Wash (DIRS 152511-Brocoum 2000, pp. A-9 to A-13). There is no designated game habitat at the proposed location for the intermodal transfer station, but the adjacent Meadow Valley Wash is classified as important habitat for water fowl and Gambel's quail (DIRS 104593-CRWMS M&O 1999, p. 3-30). Impacts to this habitat would be small.

Moist areas in the proposed location and the adjacent perennial stream and riparian habitat along Meadow Valley Wash could be classified as jurisdictional wetlands or other waters of the United States, although no formal wetlands delineation of the area has been conducted. If this site was selected, DOE would delineate the boundaries of any jurisdictional wetlands, develop a plan to mitigate impacts, and consult with the U.S. Army Corps of Engineers regarding the need to obtain a regional or individual permit under Section 404 of the Clean Water Act.

The predominant land cover types along the Caliente route are salt desert scrub, sagebrush, and creosote-bursage (DIRS 104593-CRWMS M&O 1999, p. 3-30). The regional area for each vegetation type is extensive (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way, and have been previously degraded by human activities, impacts would be small. In addition, vegetation would be removed from approximately 0.04 square kilometer (10 acres) of undisturbed land for development of a midroute stopover. This area would be east of the City of Tonopah. The precise location is not known at this time, so the land cover type that would be disturbed cannot be identified. However, as noted above, all land cover types along the route are extensive and often degraded in the region, so loss of this area would be unlikely to cause adverse effects to the population of any plant or animal species.

Three threatened or endangered species occur along the Caliente route (DIRS 104593-CRWMS M&O 1999, p. 3-30). The desert tortoise occurs along the southern part of the route along U.S. 95 from Beatty to Yucca Mountain. Construction activities could kill or injure some tortoises; however, their abundance is low in this area (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411), so losses would be small. One endangered species—the Hiko White River springfish—occurs in Crystal Springs (50 CFR 17.95). The outflow of the spring comes within about 10 meters (33 feet) of State Route 375 near its intersection with State Route 318 near U.S. 93 (DIRS 104593-CRWMS M&O 1999, p. 3-30). Therefore, any upgrading of the road in this area could have the potential to affect critical habitat. DOE would ensure that construction activities avoided the spring outflow channel and would implement mitigation measures to ensure that no sediment entered the stream. In addition, formal consultation with the U.S. Fish and Wildlife Service would be initiated if this heavy-haul truck route was selected, and DOE would implement all terms and conditions required by the Service.

An introduced population of the threatened Railroad Valley springfish occurs in Warm Springs (DIRS 103261-FWS 1996, p. 20), the outflow of which crosses U.S. 6. If improvements to the highway in the vicinity of the Warm Springs outflow were necessary, there could be temporary adverse impacts to this introduced population due to habitat disturbance and siltation if not properly mitigated. Six other special status species occur along this route (DIRS 104593-CRWMS M&O 1999, pp. 3-30 and 3-31) but, because construction activities would be limited to the road and adjacent areas and care would be taken to ensure no sediments entered the streams, species should not be affected.

This route would cross eight areas designated as game habitat (DIRS 104593-CRWMS M&O 1999, p. 3-31). The amount of habitat in these areas would be reduced slightly due to construction activities alongside existing roads. Game animals in these areas during construction could be disturbed.

Nineteen springs occur near this route (DIRS 104593-CRWMS M&O 1999, p. 3-31). Areas around these springs may be jurisdictional wetlands or waters of the United States. However, no formal delineation has been made. Construction could increase sedimentation in these areas. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and would obtain individual or regional permits, as appropriate.

Impacts on soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along the route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

6.3.3.2.1.4 Caliente Route Cultural Resources

Highway Construction and Upgrades. Previous surveys have recorded a total of 178 archaeological sites within the existing rights-of-ways of the highways that make up this alternative. Upgrade of highways associated with the Caliente heavy-haul truck route would affect (by disturbing the sites or crushing artifacts) two known archaeological sites in the existing highway right-of-way [about 60 meters (200 feet)] that have been evaluated as potentially significant (DIRS 155826-Nickens and Hartwell 2001, p. 12). In addition, another 20 archaeological sites occur in areas in the existing right-of-way that would experience upgrade activities. These sites have been recorded but not evaluated, and include one historic grave along the highway south of Tonopah. This route passes through the southern area of the Tonopah Multiple Resource Area historic mining district and the Goldfield Historic District, both of which are listed on the *National Register of Historic Places*. At Tonopah, the historic district lies north of the junction of U.S. Highways 6 and 95, and heavy-haul truck traffic would not affect the historic components of this district. Although U.S. 95 passes through the heart of the historic district at Goldfield, which includes commercial and private residence buildings in the downtown area, adverse effects from heavy-haul traffic would be unlikely. Two listed historic properties are located in downtown Caliente, near the highways leading from the Caliente intermodal transfer station site. Both of these, the State-listed Smith Hotel and the National Register-listed Union Pacific Depot, are far enough from the highway route that potential impacts are unlikely.

Preliminary studies have identified several areas important to Native Americans along the Caliente heavy-haul truck route that would require additional field ethnographic studies (DIRS 155826-Nickens and Hartwell 2001, Table 8). These include Oak Springs Summit and Six-Mile Flat/Pahroc Summit along U.S. 93 west of Caliente; Crystal Springs, at the junction of U.S. 93 and State Route 375; Twin Springs, Twin Springs slough, and Echo Lakes area, along State Route 375 between Rachel and Warm Springs; and the Warm Springs/Hot Creek Valley area, at the junction of State Route 375 and U.S. 6.

Archaeological surveys at the candidate Caliente intermodal transfer station site just south of the City of Caliente recorded four sites, none of which has been evaluated for eligibility to the *National Register of Historic Places.* Native Americans are familiar with some of these sites, which include a series of painted and pecked rock art, along the cliff immediately west of the candidate intermodal transfer station site (DIRS 155826-Nickens and Hartwell 2001, Table 8). The rock art is adjacent to the flat area where DOE could construct an intermodal transfer station. Although direct impacts to the site would be unlikely, indirect impacts are a possibility. Native Americans would view the presence of an intermodal transfer station near a traditional site as an impact to their cultural values.

Operations. The use of existing highways for heavy-haul truck transport of spent nuclear fuel and high-level radioactive waste would be unlikely to affect historic buildings listed in the National Register district in the Town of Goldfield. Transport of these materials could affect Native American feelings for the potentially significant cultural areas identified along the highways.

The operation of a Caliente intermodal transfer station could have a lasting impact on the cultural integrity of the location, which Native Americans have identified as an important place.

6.3.3.2.1.5 Caliente Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente route. Impacts of the associated intermodal transfer station are the same for each heavy-haul truck implementing alternative and are in Section 6.3.3.1.

Highway Construction and Upgrades. Industrial safety impacts on workers from the upgrade of highways and use of the Caliente route would be small (see Table 6-93). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities due to commuting workers and transporting construction materials and equipment. Table 6-94 lists the estimated fatalities from construction vehicle and commuter traffic.

Operations. The incident-free radiological impacts listed in Table 6-95 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste using the Caliente route. These impacts include transportation along the highway route as well as transportation along railways in Nevada to the Caliente intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-93. Impacts to workers from industrial hazards during the Caliente route construction upgrades.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	66	220
Lost workday cases	33	120
Fatalities	0.09	0.61
Noninvolved workers[d]		
Total recordable cases	4.0	13
Lost workday cases	1.5	4.7
Fatalities	0.004	0.01
Totals[e]		
Total recordable cases	70	240
Lost workday cases	34	127
Fatalities	0.1	0.6

a. Impacts are totals for about 35 months.
b. Includes impacts from periodic resurfacing and maintenance; impacts are totals for 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Table 6-94. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente route for heavy-haul trucks.[a]

Activity	Kilometers[b]	Traffic fatalities	Vehicle emissions fatalities
Construction[c]			
Material delivery vehicles	60,000,000	1.0	0.12
Commuting workers	50,000,000	0.5	0.07
Subtotals[d]	*110,000,000*	*1.5*	*0.19*
Operations[e]			
Commuting workers	200,000,000	2.0	0.26
Totals	***310,000,000***	***3.5***	***0.45***

a. Includes impacts from the construction and operation of an intermodal transfer station.
b. To convert kilometers to miles, multiply by 0.62137.
c. Impact totals are for about 35 months.
d. Totals might differ from sums of values due to rounding.
e. Impact totals are for 24 years.

Table 6-95. Health impacts from incident-free Nevada transportation for the Caliente route implementing alternative.[a]

Category	Legal-weight truck shipments[b]	Rail and heavy-haul truck shipments[c]	Totals[d]
Involved workers			
Collective dose (person-rem)	38	1,600	1,600
Estimated latent cancer fatalities	0.02	0.64	0.66
Public			
Collective dose (person-rem)	7	70	77
Estimated latent cancer fatalities	0.003	0.04	0.04
Estimated vehicle emission-related fatalities	0.0016	0.015	0.016

a. Impacts are totals for 24 years.
b. Impacts of 1,079 legal-weight truck shipments from six commercial sites.
c. Includes impacts to workers at an intermodal transfer station and impacts to escorts.
d. Totals might differ from sums of values due to rounding.

6.3.3.2.1.6 Caliente Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways on the Caliente route and building an intermodal transfer station for heavy-haul truck transportation. The discussion includes impacts from the operation of an intermodal transfer station at the Caliente site and periodic resurfacing of highways.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading highways for a Caliente route and building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. Upgrading the roads for the route would cost about $125 million, and would require about 653,000 worker hours and 35 months to complete. Constructing an intermodal transfer station would cost $25 million and require approximately 18 months to complete. (Dollar values reported in this section are 2001 dollars unless stated otherwise.)

Employment. In the region of influence, increased employment of construction workers involved with upgrading highways or with building an intermodal transfer station (direct workers) and other workers employed as a result of the economic activity generated by the project (indirect workers) would peak in 2008 at about 856 workers. The increase in employment in Clark County would be about 748 workers; Nye and Lincoln Counties would each gain 54. The increases in Clark and Nye Counties would be less than 1 percent of the employment baseline for each county. The increase in Lincoln County employment would be 2.2 percent of the county's employment baseline.

In the three-county region of influence, employment of Caliente route construction workers and of indirect workers would decrease by 738 jobs when the construction of an intermodal transfer station and highway upgrades ended in 2009. At the completion of the construction phase, Clark County would lose 720 of these jobs, Nye County would lose 6, and Lincoln County would lose 12. The impacts would be less than 1 percent of the baselines in Clark and Nye Counties. DOE anticipates that project-related workers would be absorbed in other work in Nevada. Employment projections for the State estimate 1.4 million jobs in 2010.

Population. Projected population increases in the region of influence as a consequence of upgrading highways and constructing an intermodal transfer station for the Caliente route would peak in 2009. During that year, the incremental increase in population would be about 688 individuals. Ninety-one percent (627) of these individuals would live in Clark County, 42 in Nye County, and 18 in Lincoln County. Population changes for Clark, Lincoln, and Nye Counties that would arise from increased employment opportunities would be less than 1 percent of each county's population baseline. Because the increases in each county could be small and transient, impacts to schools or housing would be unlikely.

Economic Measures. Economic measures would rise during the construction of an intermodal transfer station and upgrading of highways, and would decline at the project's end. The temporary change in real disposable income of people in the three-county region of influence would peak in 2008 at $26.5 million. The region-wide change in Gross Regional Product would peak in 2008 at $45.3 million. Increased State and local government expenditures resulting from activities to upgrade highways and construct an intermodal transfer station would peak in 2009 at $2.3 million. The Gross Regional Product, real disposable income, and expenditures by local and State governments would be less than 1 percent higher than the baseline for Clark and Nye Counties. Lincoln County would experience a less-than-1-percent increase in real disposable income and government spending. The increase in Gross Regional Product ($1.4 million) would be 1.2 percent of the county's baseline. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Caliente heavy-haul truck route workers and indirect (support) workers would decrease by 738 when construction of the intermodal transfer station and highway upgrades ended in 2009. Clark County would lose 721 (98 percent) of these jobs. Nye County would lose 5 jobs, and Lincoln County would lose 12 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Caliente route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and continue until 2033. An annual operations workforce of about 26 would be required for an intermodal transfer station, which would operate throughout the year. The direct workforce for heavy-haul truck operations over a Caliente route, including shipment escorts, would be about 120 workers. The analysis assumed that operations workers would reside in Clark, Lincoln, or Nye Counties.

Employment. Employment probably would remain relatively level throughout the operations period. Total employment (direct and indirect) in the region of influence associated with heavy-haul truck transportation and an intermodal transfer station would average about 274 workers. The baseline employment in the region of influence in the 24-year operations period would be about 1.1 million. Firms in the region of influence would employ about 94 percent of these workers. Clark County would gain 111 workers. Nye County would gain 74, and Lincoln County would gain 88. The increases in Clark and Nye Counties would be less than 1 percent of the respective baselines. The increase in Lincoln County would represent 3.3 percent of the county's employment baseline.

Because of the periodic need to resurface highways used by heavy-haul trucks (every 8 years starting in 2016), employment would increase in the years these projects occurred. For these projects, employment (direct and indirect) in the region would increase by about 250 workers. Employment changes from periodic highway-resurfacing projects would be less than 1 percent of the baseline in Clark County. DOE assumed that Clark County-based firms would employ the resurfacing project workers. DOE included the employees who would resurface the roads and their families in the employment and population estimates discussed above for the operations period. Overall impacts to employment and population as a result of highway maintenance and shipment operations would be less than 1 percent of the baselines in each county.

Population. The average annual increase in population in the region of influence as a result of employment associated with a Caliente heavy-haul truck route would be about 638 persons. DOE estimates that about 387 of these would reside in Clark County, about 134 in Nye County, and 117 in Lincoln County. Population increases for Lincoln County, which would experience the largest change as a percentage of the baseline, would be about 2.4 percent.

The change in population in Lincoln County would include an average annual increase of approximately 27 school-aged children. The impact to housing in the county would be negligible given the county's historically high housing vacancy rates (see Chapter 3, Section 3.1.7.4). Impacts attributable to the operation of the Caliente heavy-haul truck route would be within the range of historic changes in the county.

Economic Measures. In the region of influence, real disposable income from the operation of an intermodal transfer station in Caliente, operation of heavy-haul trucks based in Caliente, and periodic resurfacing of the roads would rise during operations, starting at $4.1 million in 2010 and rising to $22 million in 2033. The average annual impact in real disposable income would be $12.9 million. Gross Regional Product would also rise during operations, increasing to $29 million in 2033 and averaging $15.3 million. Annual State and local government expenditures attributable to this heavy-haul truck implementing alternative would increase from $2.2 million in 2010 to $4.0 million in 2033, with an annual average of $2.9 million. The impact of changes in the economic measures of Gross Regional Product, real disposable income, and expenditures by State and local governments would be less than 1 percent for Clark and Nye Counties. The impact in Lincoln County would be more visible. Changes in real disposable income would average 2.4 percent of the baseline, the impact in Gross Regional Product would average 3.7 percent of the baseline, and the change in expenditures by State and local governments would average 2.9 percent of the baseline in the county.

In addition, DOE analyzed a sensitivity case that assumed all Lincoln County socioeconomic impacts would occur only in the City of Caliente. Under this assumption, City population would rise by 3 percent during construction and by about 8.7 percent during operations. Employment would rise by about 11 percent during construction and about 12 percent during operations.

6.3.3.2.1.7 Caliente Route Noise and Vibration

Section 6.3.3.1 discusses the noise impacts common to all heavy-haul truck implementing alternatives. This section focuses on noise impacts that would be unique to the Caliente heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The Caliente intermodal transfer station would border a wastewater-treatment facility consisting of drain fields and ponds. There is a single dwelling about 500 meters (1,600 feet) to the northeast of a 0.26-square kilometer (64-acre) parcel that has been identified as a potential site for the Caliente intermodal transfer station. However, this residence is behind a small rise and would be partially shielded from operations at an intermodal transfer station. As a consequence, the potential for noise impacts from construction and operations would be very low at this location.

Operations. Existing traffic on the candidate routes for heavy-haul trucks includes a significant component of tractor-trailer vehicles. Because the intermodal transfer station would be on the western edge of Caliente, traffic to and from the station would not travel through town. Traffic noise impacts in Caliente would be inconsequential. The increase in 1-hour average noise levels would be greatest near Rachel, where traffic volumes are lowest. The estimated elevation of background traffic noise would be 4.7 dBA 15 meters (49 feet) from the road. The estimated baseline traffic noise level of 59.2 dBA would increase to 63.9 dBA when heavy-haul trucks passed Rachel. Estimated traffic noise levels in Tonopah, Goldfield, and Beatty would increase by 0.3 to 2.0 dBA. These small increases in noise levels would not be discernable when compared to existing background levels of current tractor-trailer noise in these communities. Heavy-haul trucks would add only a small increment to the existing baseline noise level associated with traffic on these routes. U.S. 95 is a major transportation corridor for the trucking industry from central California to Las Vegas. U.S. 6, State Route 373 and U.S. 93 (from Crystal Springs to Caliente) carry less traffic than U.S. 95. Ground vibrations would not affect any historic buildings because of the low speeds that heavy-haul trucks would use when passing through Goldfield. No sensitive ruins of cultural significance have been identified along this route.

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The Caliente route passes the northeastern border of the Timbisha Shoshone Trust Lands parcel on U.S. 95. Estimated mean 1-hour increases in traffic noise due to heavy-haul trucks in this area would be 0.8 dBA over existing background traffic noise (DIRS 155825-Poston 2001, all). This level of increase would not cause adverse impacts.

6.3.3.2.1.8 Caliente Route Aesthetics

A Caliente intermodal transfer station would be located near the entrance to Kershaw-Ryan State Park. In addition, park visitors would receive short-term visual impacts from construction activities. Park visitors could also be affected by noise from construction activities that could lessen their recreational experience. These short-term impacts would exist only during construction.

During operation of the intermodal transfer station, noise and lighting probably would be discernible from Kershaw-Ryan State Park, especially during night operations, and would probably detract from the recreational experience. The use of shielded and directional-lighting would limit the amount of viewable light from outside the facility operational area.

6.3.3.2.1.9 Caliente Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses the utilities, energy, and materials impacts that would be common to the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Caliente heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Caliente intermodal transfer station would have the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

Table 6-96 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Caliente route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-96. Utilities, energy, and materials required for upgrades along the Caliente route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente	533	13	220	1.4	1.8	49.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses the utilities, energy, and material needs for operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.2 *Caliente/Chalk Mountain Route Implementing Alternative*

The Caliente/Chalk Mountain route (Figure 6-23) is approximately 282 kilometers (175 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel on U.S. 93 to State Route 375, then on State Route 375 to the Town of Rachel. Next they would head south on Valley Road through the Nellis Air Force Range past Chalk Mountain to the Groom Pass Gate to the Nevada Test Site.

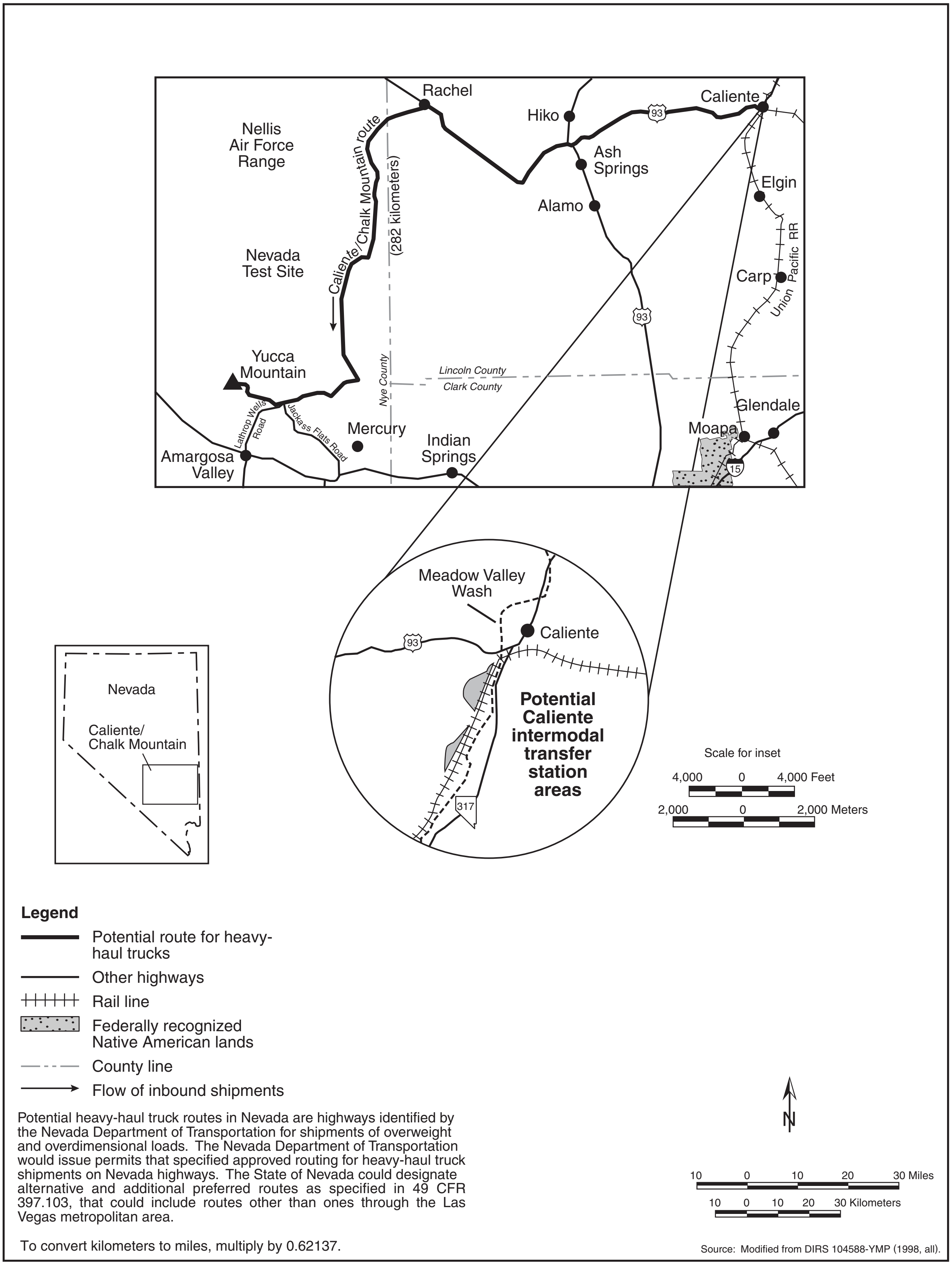


Figure 6-23. Caliente/Chalk Mountain heavy-haul truck route.

DOE would construct a parking area along a Caliente/Chalk Mountain route near the northern boundary of the Nellis Air Force Range to enable heavy-haul vehicles to park overnight. This parking area could be needed because the travel time (vehicle in motion plus periodic short stops for inspections) associated with a Caliente/Chalk Mountain route would be as much as 8 hours and because (1) DOE anticipates restrictions on the times trucks could travel across the Nellis Air Force Range and (2) special travel permits issued by the State of Nevada for the trucks would include time-of-day and day-of-the-week travel restrictions. The estimated life-cycle cost to construct and operate an intermodal transfer station and to operate heavy-haul trucks along the Caliente/Chalk Mountain route would be about $548 million in 2001 dollars.

Section 6.3.3.2.1 discusses the Caliente siting areas for an intermodal transfer station.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics and utilities, energy, and materials. Impacts that would occur to air quality, and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.2.2.1 Caliente/Chalk Mountain Route Land Use and Ownership

This section describes anticipated land-use impacts that could occur from the construction and operation of the Caliente intermodal transfer station, upgrades of highways, and heavy-haul truck operations over the Caliente/Chalk Mountain route. Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and the associated route to the Yucca Mountain site.

Highway Construction and Upgrades. Section 6.3.3.2.1 discusses Caliente intermodal transfer station impacts in relation to the current use of the land and the surrounding area. Section 6.3.3.1 describes impacts on land use from upgrading highways for use by heavy-haul trucks.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 1.3 square kilometers (310 acres) of land would be disturbed by the road upgrades and additional construction activities required for this route. Table 6-97 summarizes these disturbances. Approximately 0.04 square kilometer (10 acres) of land in the vicinity of the northern boundary of the Nellis Air Force Range would be acquired for a midroute stopping area for heavy-haul trucks.

Table 6-97. Land disturbances along the Caliente/Chalk Mountain heavy-haul truck route.

Disturbance	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	0.6
Aggregate plants	0.1
Road widening	0.3
Passing lanes	0.1
Truck turnouts	0.02
Fortymile Wash new road	0.04
Overnight stops	0.04
Total disturbed area	1.3

a. Numbers approximate due to rounding.
b. To convert square kilometers to acres, multiply by 247.1.

The Caliente/Chalk Mountain route would involve land controlled by the Nellis Air Force Range (also known as the Nevada Test and Training Range), which, according to the Air Force, would affect Air Force operations. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65, 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to operate a heavy-haul truck route through any part of the Range. The Air Force has identified national security issues regarding a Caliente/Chalk Mountain route, citing interference with Nellis Air Force Range testing and training activities. In response to Air Force concerns, DOE has stated that it is acutely conscious of the security issues such a route would present and, because of the concerns expressed by the Air Force, regards the route as a "non-preferred alternative."

Operations. The Air Force has identified national security issues regarding operations of heavy-haul trucks on the Caliente/Chalk Mountain route, citing interference with Nellis Air Force Range testing and training activities. There would be no other direct land-use impacts associated with the operation of the Caliente intermodal transfer station or the Caliente/Chalk Mountain route except those described above and in Section 6.3.3.1.

6.3.3.2.2.2 Caliente/Chalk Mountain Route Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so that they could accommodate daily use by heavy-haul trucks. This section discusses these potential environmental impacts as well as those from the construction and operation of an intermodal transfer station and operation of the Caliente/Chalk Mountain route. Section 6.3.3.1 discusses the hydrological impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Caliente/Chalk Mountain route.

Surface Water

Section 6.3.3.1 discusses the impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways.

Appendix L contains a comparison of what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.6 and L.4.2.2). As noted in Section L.3.2.6, the two locations being considered for the Caliente intermodal transfer station are outside the 100-year flood zone of Meadow Valley Wash, but inside the 500-year flood zone.

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. Upgrades to the Caliente/Chalk Mountain route would require about 75,000 cubic meters (60 acre-feet) of water (DIRS 104917-LeFever 1998, all) that the analysis assumed would come from five wells.

The average amount of water withdrawn from each well would be about 15,000 cubic meters (12 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies hydrographic areas over which the Caliente/Chalk Mountain route would pass, their perennial yields, and whether the State considers each a Designated Groundwater Basin. Table 6-98 summarizes the status of the hydrographic areas associated with the Caliente/Chalk Mountain heavy-haul truck route. It also identifies the approximate percentage of the route that would pass over Designated Groundwater Basins.

Table 6-98. Hydrographic areas along Caliente-Chalk Mountain route.

Hydrographic areas	Designated Groundwater Basins: Number	Designated Groundwater Basins: Percent of corridor length
10	2	20

The withdrawal of 15,000 cubic meters (12 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente/Chalk Mountain route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-98, about 20 percent of the route's length would be in areas with Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for the potential for groundwater depletion. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. The fact that requests for water appropriations under this action would be for minor amounts and for a short-term construction action should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (4,000 truckloads) to construction sites, or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses the impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

6.3.3.2.2.3 Caliente/Chalk Mountain Route Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all candidate sites for an intermodal transfer station and routes. This section discusses the construction- and operations-related impacts that would be unique to the Caliente intermodal station and Caliente/Chalk Mountain route.

Highway Construction and Upgrades. Section 6.3.3.2.1 discusses potential Caliente intermodal transfer station site locations and impacts to biological resources from station construction.

The predominant land cover types along the Caliente/Chalk Mountain route are salt desert scrub, blackbrush, sagebrush, and creosote-bursage (DIRS 104593-CRWMS M&O 1999, p. 3-31). The regional area for each vegetation type is extensive (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5). Because areas disturbed by highway upgrade activities would be in or adjacent to existing rights-of-way, and because these areas have been previously degraded by human activities, impacts would be small. In addition, vegetation would be removed from approximately 0.04 square kilometer (10 acres) of undisturbed land for development of a midroute stopover. This area would be near or outside the boundary of Nellis Air Force Range. The precise location is not known at this time, so the land cover type that would be disturbed cannot be identified. However, as noted above, all land cover types along the route are extensive and often degraded in the region, so the loss of this area would be unlikely to cause adverse effects to the population of any plant or animal species.

Two threatened or endangered species occur along the route (DIRS 104593-CRWMS M&O 1999, p. 3-32). The desert tortoise occurs along the southern part of the route from the northern end of Frenchman Flat to Yucca Mountain. Construction activities could kill or injure desert tortoises; however, their abundance is low in this area (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411), so losses would be few. One endangered species—the Hiko White River springfish—occurs in Crystal Springs (DIRS 103262-FWS 1998, p. 16), which is about 10 meters (33 feet) south of State Route 375 near its intersection with State Route 318 near U.S. 93. Construction or widening of the road would be unlikely to affect this species because construction activities would avoid the spring outflow channel, and DOE would implement mitigation measures to ensure that no sediment would enter the stream, which is critical habitat for this fish (50 CFR 17.95). Three other special status species occur along this route, but because construction activities would occur along existing roads, they should not be affected. Standard construction practices would be used to reduce erosion and runoff. In addition, formal consultation with the U.S. Fish and Wildlife Service would be initiated if this heavy-haul truck route was selected, and DOE would implement all terms and conditions required by the Service.

This route would cross six areas designated as game habitat (DIRS 104593-CRWMS M&O 1999, p. 3-32). The amount of habitat in these areas would be reduced very slightly due to construction activities along existing roads. Game animals could be disturbed if they were in these areas during construction.

Three springs or riparian areas occur near this route (DIRS 104593-CRWMS M&O 1999, p. 3-32). These springs and riparian areas may be jurisdictional wetlands or other waters of the United States; however, no formal delineation has been made. DOE would implement mitigation measures to ensure that construction would not increase sedimentation in these areas. The route crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits, as appropriate.

Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

6.3.3.2.2.4 Caliente/Chalk Mountain Route Cultural Resources

Highway Construction and Upgrades. Upgrades to U.S. 93 and State Route 375 would create similar impacts (such as disturbing sites or crushing artifacts) for archaeological, historic, and Native American resources as those identified with the use of the Caliente heavy-haul truck route. Potential impacts at the Caliente intermodal transfer station would also be the same.

Surveys have recorded 31 archaeological sites, five of which have been evaluated as being potentially significant. One is a historic mining camp that has not been evaluated. Additional field surveys would be necessary to record and evaluate cultural resource sites along the route segment from State Route 375 to Yucca Mountain, along with field ethnographic studies. Within the Nevada Test Site, the National Register-listed historic property of Sedan Crater would be located close to, but at a presently unspecified distance, from the proposed new route heavy-haul segment. If this route is selected, final engineering of the alignment would determine if there would be any potential impacts to this historic property.

Table 6-99. Impacts to workers from industrial hazards from upgrading highways along the Caliente/Chalk Mountain route.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	35	220
Lost workday cases	17	120
Fatalities	0.05	0.61
Noninvolved workers		
Total recordable cases	2.1	13
Lost workday cases	0.8	4.7
Fatalities	0.002	0.01
otals[d]		
Total recordable cases	37	240
Lost workday cases	18	130
Fatalities	0.05	0.62

a. Impacts are totals over about 2 years.
b. Includes impacts from periodic maintenance and resurfacing. Impacts are totals over 24 years.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

Operations. Impacts from the use of the Caliente/Chalk Mountain route from the Caliente intermodal transfer station to the point at which it leaves State Route 375 would be the same as those identified for the Caliente route in Section 6.3.3.2.1.

6.3.3.2.2.5 Caliente/Chalk Mountain Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente/Chalk Mountain route. Impacts of the associated intermodal transfer station in Caliente would be the same as those discussed in Section 6.3.3.1.

Highway Construction and Upgrades. Industrial safety impacts to workers from upgrading highways for the Caliente/Chalk Mountain route would be small (Table 6-99). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-100 lists the estimated fatalities from construction and commuter vehicle traffic.

Table 6-100. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente/Chalk Mountain route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	18,000,000	0.3	0.04
Commuting workers	30,000,000	0.3	0.04
Subtotals	*48,000,000*	*0.6*	*0.08*
Operations[c]			
Commuting workers	180,000,000	1.8	0.24
Totals[d]	***230,000,000***	***2.4***	***0.32***

a. To convert kilometers to miles, multiply by 0.62137.
b. Impacts are totals over about 2 years.
c. Impacts are totals over about 24 years.
d. Totals might differ from sums of values due to rounding.

Operations. The incident-free radiological impacts listed in Table 6-101 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste using the Caliente/Chalk Mountain route. These impacts include transportation along the route and along railways in Nevada leading to an intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-101. Impacts from incident-free transportation for the Caliente/Chalk Mountain heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	38	1,200	1,200
Estimated latent cancer fatalities	0.02	0.48	0.5
Public			
Collective dose (person-rem)	7	60	70
Estimated latent cancer fatalities	0.003	0.03	0.03
Estimated vehicle emission-related fatalities	0.0016	0.0063	0.0079

a. Impacts are totals for 24 years.
b. Includes impacts to workers at an intermodal transfer station and impacts to escorts.
c. Totals might differ from sums of values due to rounding.

6.3.3.2.2.6 Caliente/Chalk Mountain Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways along the Caliente/Chalk Mountain route and building an intermodal transfer station for heavy-haul truck transportation. The discussion includes the impacts from the operation of an intermodal transfer station at Caliente and periodic resurfacing of the highways.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading public highways, roads on the Nellis Air Force Range, and roads on the Nevada Test Site for a Caliente/Chalk Mountain route and for building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. Employment for highway upgrades and intermodal transfer station construction would involve workers laboring for about 241,000 worker hours. Upgrading the highways along this route would cost about $65.6 million and would require 26 months to complete.

Constructing an intermodal transfer station would cost $25 million and require 18 months. (Dollar values reported in this section are 2001 dollars unless otherwise stated.)

Employment

In the region of influence, increased employment of construction workers involved with upgrading the highways or with building an intermodal transfer station (direct workers) and of other workers employed as a result of the economic activity generated by the project (indirect workers) would peak in 2008 at about 751 new jobs. The increase in employment for Clark County would be about 650 workers and Nye County would gain 44 workers. These increases represent less than 1 percent of each county's employment baseline. For Lincoln County, the increase in employment would be as much as 57 workers or 2.3 percent of the employment baseline. Changes in Lincoln County would be primarily the result of indirect employment created by the spending of construction workers.

Population

Changes in population in the region of influence as a consequence of construction work would peak in 2009. During that year, the incremental increase in population would be about 463 individuals. Clark County would experience 91 percent of the change. Population changes for Clark, Lincoln, and Nye Counties from increased employment would be less than 1 percent of each county's baseline. Because employment and population impacts arising from highway upgrade and the construction of an intermodal transfer station for the Caliente/Chalk Mountain route projects would be small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Economic measures would rise during the construction of an intermodal transfer station and upgrading of highways. The increase in real disposable income in the three counties in the region of influence would peak at about $21.8 million in 2009. Gross Regional Product would peak in 2008 at $39.8 million. Increased State and local government expenditures resulting from highway upgrades and the construction of an intermodal transfer station would reach their peak in 2009 at $1.6 million. Changes to government expenditures and real disposable income would be less than 1 percent of the respective baselines for Clark, Lincoln, and Nye Counties. Changes to Gross Regional Product in Clark and Nye Counties would also be less than 1 percent of the baselines. The increase in Gross Regional Product in Lincoln County would be about 1.2 percent of the county's baseline for that economic measure. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Caliente/Chalk Mountain heavy-haul truck route workers and indirect (support) workers would decrease by 677 when construction of the intermodal transfer station and highway upgrades ended in 2009. Clark County would lose 506 (83 percent) of these jobs. Nye County would lose 41 jobs, and Lincoln County would lose 33 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Caliente/Chalk Mountain route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and would continue until 2033. An annual operations workforce of 26 would be required for the intermodal transfer station. The workforce for heavy-haul truck operations over a Caliente/Chalk Mountain route, including shipment escorts, would be 110 workers.

Employment

Employment probably would remain relatively level throughout operations. Total employment (direct and indirect) attributable to the Caliente/Chalk Mountain route in the region of influence would average about 237 jobs. Clark County would supply about 87 of the workers, Nye County about 17, and Lincoln

County about 133. The increase in employment in Clark and Nye Counties would be less than 1 percent of each county's employment baseline. The increase in employment in Lincoln County would represent an impact of 4.9 percent of the county's employment baseline.

Because of the periodic need to resurface highways used by heavy-haul trucks (every 8 years starting in 2016), employment would increase in the years during which these projects occurred. For these projects, total employment in the region of influence would increase by about 100 workers for a Caliente/Chalk Mountain route. Employment changes from periodic highway-resurfacing projects would be less than 1 percent of the baseline in Clark County. DOE assumed that resurfacing project workers would live in Clark County. DOE included the workers employed to resurface the roads and their families in the employment and population estimates for the operations period. Impacts to employment and population for the three counties in the region of influence as a consequence of the resurfacing projects would be less than 1 percent of the baselines.

Population

The impact on population in the region of influence would be approximately 506 additional residents. Clark County would gain 296 residents, Nye County would gain 43, and Lincoln County would gain 167. The impact from a population increase in Clark and Nye Counties would be less than 1 percent of each county's baseline. There would no impacts to housing or schools in Clark and Nye Counties. Population increases for Lincoln County, which would experience the largest change, would be approximately 3.5 percent of the baseline. These impacts to employment and population during the operations phase would be within the range of historic changes in the County.

The population change in Lincoln County would include an average annual increase of approximately 38 school-aged children. The impact to housing attributable to the Caliente/Chalk Mountain heavy-haul route would be negligible given the County's historically high housing vacancy rates (see Chapter 3, Section 3.1.7.4).

Economic Measures

In the region of influence, additional real disposable income from the operation of an intermodal transfer station in Caliente, operation of heavy-haul trucks, and periodic resurfacing of the roads would rise throughout operations, starting at $3.9 million in 2010 and increasing to $15.8 million in 2033. The average annual increment in real disposable income would be $11.1 million. Increments to Gross Regional Product would also rise during operations, starting at $2.4 million in 2010, increasing to $20.4 million in 2033, and averaging $13.7 million. Additional annual State and local government expenditures would increase from $1.6 million in 2010 to $3.8 million in 2033, and would average $2.8 million. The increases in real disposable income, Gross Regional Product, and expenditures by governments would be less than 1 percent of the applicable baseline in Clark and Nye Counties. Increases to real disposable income, Gross Regional Product, and government expenditures attributable to the Caliente/Chalk Mountain route would be more visible in Lincoln County. Changes in real disposable income and government expenditures for the county would be about 3.3 and 4.2 percent, respectively, of the baselines. The projected change in Gross Regional Product for the County would be 5.1 percent of the baseline.

In addition, DOE analyzed a sensitivity case that assumed all Lincoln County socioeconomic impacts would occur only in the City of Caliente. Under this assumption, City population would rise by 3 percent during construction and by about 8.7 percent during operations. Employment would rise by about 11 percent during construction and about 12 percent during operations.

6.3.3.2.2.7 Caliente/Chalk Mountain Route Noise and Vibration

Section 6.3.3.1 discusses the noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on noise impacts that would be unique to the Caliente/Chalk Mountain heavy-haul truck implementing alternative.

Noise impacts of the Caliente intermodal transfer station would be the same as those discussed in Section 6.3.3.2.1. A large portion of the route would be inside the boundaries of the Nevada Test Site and the Nellis Air Force Range. The small rural communities of Crystal Spring and Rachel and the Town of Caliente would be within the 2,000-meter (6,600-foot) region of influence for construction noise.

Existing traffic on the candidate routes for heavy-haul trucks includes a significant component of tractor-trailer vehicles. The increase in 1-hour average noise levels would be greatest near Rachel, where traffic volumes are lowest. The estimated elevation of background traffic noise would be 0.6 dBA 15 meters (49 feet) from the road. The estimated baseline traffic noise level would be 61.4 dBA, which would increase to 62.4 dBA with three heavy-haul trucks passing Rachel. Because the proposed intermodal transfer station would be on the western edge of Caliente and traffic would not travel through town, traffic noise impacts in Caliente would be inconsequential. No historic buildings would be affected by ground vibration.

6.3.3.2.2.8 Caliente/Chalk Mountain Route Aesthetics

A Caliente intermodal transfer station would be near the entrance to Kershaw-Ryan State Park. Park visitors would receive short-term visual impacts from construction activities. In addition, park visitors could be affected by noise from construction activities that could lessen their recreational experience. These short-term impacts would exist only during construction.

During operation of the intermodal transfer station, noise and lighting probably would be discernible from Kershaw-Ryan State Park, especially during night operations, and would probably detract from the recreational experience. The use of shielded and directional lighting would limit the amount of viewable light from outside the facility operational area.

6.3.3.2.2.9 Caliente/Chalk Mountain Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy and materials impacts that would be unique to the Caliente/Chalk Mountain heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Caliente intermodal transfer station would have the same utilities, energy and materials impacts as those discussed in Section 6.3.3.1.

Table 6-102 lists the estimated quantities of primary materials for the upgrade of highways for the Caliente/Chalk Mountain route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-102. Utilities, energy, and materials required for upgrades along the Caliente/Chalk Mountain route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente-Chalk Mountain	282	4.7	77	0.41	0.5	14

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitment of resources.

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

6.3.3.2.3 *Caliente/Las Vegas Route Implementing Alternative*

The Caliente/Las Vegas route (Figure 6-24) is approximately 377 kilometers (234 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel south on U.S. 93 to the intersection with I-15 northeast of Las Vegas. The trucks would then travel south on I-15 to the exit for the proposed Las Vegas Beltway, and would travel west on the beltway. They would exit the beltway to U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

DOE would construct a parking area along a Caliente/Las Vegas route to enable heavy-haul vehicles to park overnight. This parking area could be needed because the travel time (vehicle in motion plus periodic short stops for inspections) associated with a Caliente/Las Vegas route would be as much as 9 hours and because DOE anticipates (1) requirements to coordinate travel times with time of reduced traffic flow on the northern portion of the Las Vegas Beltway and (2) special travel permits issued by the State of Nevada for the trucks would include time-of-day and day-of-the-week travel restrictions that could preclude completing a trip in 1 day. This parking area would be near the U.S. 93 and I-15 intersection at Apex. The estimated life-cycle cost of constructing and operating an intermodal transfer station and of operating heavy-haul trucks along the Caliente/Las Vegas route would be about $607 million in 2001 dollars.

Section 6.3.3.2.1 discusses the Caliente siting areas for an intermodal transfer station.

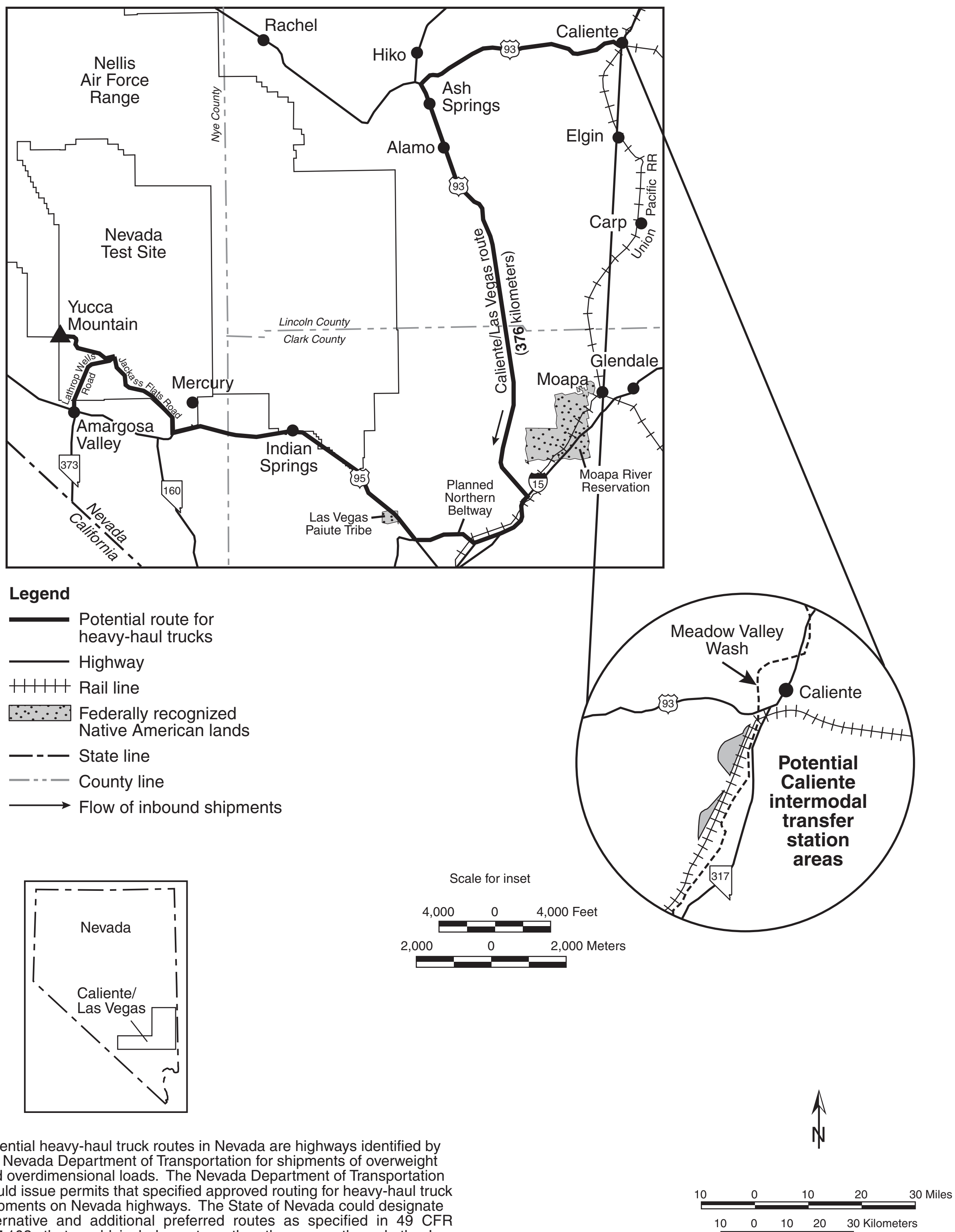
The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; and utilities, energy, and materials. Impacts that would occur to waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.2.3.1 Caliente/Las Vegas Route Land Use and Ownership

Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and associated truck route.

Highway Construction and Upgrades. Section 6.3.3.2.1 discusses the Caliente intermodal station site area and impacts related to the current use of the land. Section 6.3.3.1.1 discusses the impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 2.1 square kilometers (520 acres) of land would be disturbed by the road upgrades and additional construction activities required. Table 6-103 summarizes these disturbances. Approximately 0.04 square kilometer (10 acres) of land in the vicinity of Apex northeast of Las Vegas would be acquired for a midroute stopping area for heavy-haul trucks.



Potential heavy-haul truck routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative and additional preferred routes as specified in 49 CFR 397.103, that could include routes other than ones through the Las Vegas metropolitan area.

To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104588-YMP (1998, all).

Figure 6-24. Caliente/Las Vegas heavy-haul truck route.

Operations. There would be no direct land-use impacts associated with the operation of the Caliente intermodal transfer station or use of the Caliente/Las Vegas route other than those described in Section 6.3.3.1.

Table 6-103. Land disturbances along the Caliente/Las Vegas heavy-haul truck route.

Disturbance	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	1.2
Aggregate plants	0.2
Road widening	0.5
Passing lanes	0.08
Truck turnouts	0.02
Fortymile Wash new road	0.04
Overnight stops	0.04
Mercury turnoff road	0.03
Total disturbed area	2.1

a. Numbers approximate due to rounding.
b. To convert square kilometers to acres, multiply by 247.1.

6.3.3.2.3.2 Caliente/Las Vegas Route Air Quality

This section describes anticipated nonradiological air quality impacts from the construction and operation of an intermodal transfer station and upgrades and heavy-haul truck operation along the Caliente/Las Vegas route. Such impacts would result from releases of criteria pollutants, including nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10}) (see Section 6.3.3.1).

Carbon dioxide and PM_{10} are of particular interest along the Caliente/Las Vegas heavy-haul truck route because highway construction and upgrades and operation of heavy-haul trucks would occur through the Las Vegas Valley air basin, which is classified as a serious nonattainment area for these pollutants (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54).

Highway Construction and Upgrades. Section 6.3.3.1 discusses the method of evaluation of air quality impacts from these activities. The intermodal transfer station for this route would be outside the Las Vegas air quality nonattainment area.

PM_{10} emissions would be an estimated 66 metric tons (73 tons) per year, including estimated emissions for accelerated construction activities for the Northern Beltway. These emissions are 100 percent of the General Conformity threshold level. Extending the construction time and more diligent dust control measures would decrease annual emissions.

Carbon monoxide emissions would be an estimated 54 metric tons (59 tons) per year. These emissions are 59 percent of the General Conformity threshold level.

Operations. Section 6.3.3.1 discusses air quality impacts associated with the operation of the Caliente intermodal transfer station and from emissions of heavy-haul trucks. The Caliente/Las Vegas route would involve heavy-haul trucks passing through the Las Vegas Valley air basin. The air quality impacts to this air basin would be small [0.48 metric ton (0.53 ton) per year of carbon monoxide] with emissions of less than 1 percent of the General Conformity threshold level. These emissions would result from 11 round trips per week through the basin.

6.3.3.2.3.3 Caliente/Las Vegas Route Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these potential impacts as well as those from the construction and operation of an intermodal transfer station and operation of the Caliente/Las Vegas route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Caliente/Las Vegas heavy-haul truck implementing alternative.

Surface Water

Section 6.3.3.1 discusses impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed would apply to surface water along the Caliente/Las Vegas route.

Appendix L contains a comparison of what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.6 and L.4.2.2). As noted in Section L.3.2.6, the two locations being considered for the Caliente intermodal transfer station are outside the 100-year flood zone of Meadow Valley Wash, but inside the 500-year flood zone.

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. The upgrades to the Caliente/Las Vegas route would require about 54,000 cubic meters (44 acre-feet) of water (DIRS 104917-LeFever 1998, all) that the analysis assumed would come from seven wells.

Table 6-104. Hydrographic areas along Caliente/ Las Vegas route.

Hydrographic areas crossed	Designated Groundwater Basins: Number	Designated Groundwater Basins: Percent corridor length represented
13	5	50

The average amount of water withdrawn from each well would be about 7,700 cubic meters (6 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies the hydrographic areas over which the Caliente/Las Vegas route would pass, their perennial yields, and whether the State considers each a Designated Groundwater Basin. Table 6-104 summarizes the status of the hydrographic areas associated with the Caliente/Las Vegas route and identifies the approximate portion of the route that would pass over Designated Groundwater Basins.

The withdrawal of 7,700 cubic meters (6 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente/Las Vegas route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-104, about 50 percent of the route's length would be in areas with Designated Groundwater Basins, where the potential for groundwater depletion is watched carefully by the Nevada State Engineer's office. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. The fact that requests for water appropriations under this action would be for minor amounts and for a short-term construction action should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (about 3,000 truckloads) to construction sites, or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for a short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

6.3.3.2.3.4 Caliente/Las Vegas Route Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all potential sites for an intermodal transfer station and routes. This section discusses construction- and operations-related impacts that would be unique to the Caliente intermodal station and Caliente/Las Vegas route.

Highway Construction and Upgrades. Section 6.3.3.2.1 discusses potential Caliente intermodal transfer station siting locations and impacts to biological resources and soils from construction of the station.

The predominant land cover types along the Caliente/Las Vegas route are creosote-bursage and Mojave mixed scrub (DIRS 104593-CRWMS M&O 1999, p. 3-32). The regional area for each vegetation type is extensive (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

Four threatened or endangered species occur along the route (DIRS 104593-CRWMS M&O 1999, p. 3-33). The desert tortoise occurs along the southern part of the route from near Alamo to Yucca Mountain (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). An approximately 100-kilometer (62-mile) section of U.S. 93 from Maynard Lake to the junction with I-15 is critical habitat for the desert tortoise (50 CFR 17.95). Slight alterations of habitat immediately adjacent to existing roads would affect desert tortoises because work would occur in the existing right-of-way. Tortoise populations are depleted for more than 1 kilometer (0.6 mile) on either side of roads with average daily traffic greater than 180 vehicles (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). Two endangered species—the Pahranagat roundtail chub and the White River springfish—occur in Ash Springs or its outflow. The route crosses the outflow of Ash Springs, which is designated critical habitat for the White River springfish (50 CFR 17.95). Because improvements would occur on the existing roadway and the Nevada Department of Transportation would use standard practices to reduce erosion and runoff, road improvements would not adversely affect the species living there. Improvements to the existing highway would not affect southwestern willow flycatchers or their habitat in Pahranagat Valley (DIRS 152511-Brocoum 2000, pp. A-9 to A-13). Nine other special status species occur within 100 meters (330 feet) of this route (DIRS 104593-CRWMS M&O 1999, p. 3-33). Four of these species occur at Ash Springs or its outflow, and would not be affected for the reasons stated above for this site. The other five species would not be affected because construction activities would be restricted to the existing right-of-way, so occupied habitat would not be destroyed.

This route would cross eight areas designated as game habitat (DIRS 104593-CRWMS M&O 1999, p. 3-33). Habitat in these areas would be reduced slightly due to construction activities along existing roads. Game animals could be disrupted if they were in these areas during construction and would probably move away until the higher level of activity ceased.

Seven springs, riparian areas, or other wet areas occur near this route (DIRS 104593-CRWMS M&O 1999, p. 3-33). These areas may be jurisdictional wetlands or other waters of the United States. However, no formal delineation has occurred. Construction could increase sedimentation in these areas. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to mitigate impacts to these areas and would obtain individual or regional permits, as appropriate.

Impacts (such as increased water erosion and removal of land cover resulting in wind erosion) to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would be minimal but would include periodic disturbances of wildlife by noise from the additional truck traffic along this route. Trucks probably would kill individuals of some species, but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations.

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6.3.3.2.3.5 Caliente/Las Vegas Route Cultural Resources

Section 6.3.3.1 discusses impacts to cultural resources that would be common to all the heavy-haul truck implementing alternatives.

Highway Construction and Upgrades. Highway upgrades and construction of the Caliente/Las Vegas heavy-haul truck route would be the same from the Caliente intermodal transfer station to the junction of U.S. 93 and State Route 375, just south of Hiko, as for the Caliente route (see discussion in Section 6.3.3.2.1). Following U.S. 93 south to the Apex area, the route passes through several sites and areas that have been tentatively identified as being important to American Indians (DIRS 155826-Nickens and Hartwell 2001, Table 8). The following places have been identified in the Pahranagat National Wildlife Refuge: the Black Canyon area, the Storied Rocks site farther south, and the Maynard Lake vicinity. The Black Canyon sites are listed on the *National Register of Historic Places.*

Archaeological surveys of the highway rights-of-way along this route have identified 128 archaeological sites, seven of which have been recommended as potentially significant (DIRS 155826-Nickens and Hartwell 2001, Appendix A). Three of the potentially significant archaeological sites are located in areas identified for highway upgrades. Another 86 remain unevaluated. Two of the unevaluated sites are historic graves.

Native Americans have identified the entire Pahranagat Valley, once home to the Pahranagat Paiutes, as an important cultural landscape (DIRS 155826-Nickens and Hartwell 2001, all). Earlier studies with Native Americans identified the Coyote Springs area and the Arrow Canyon Range valley south of Pahranagat as places of cultural importance.

Operations. Operation of the Caliente intermodal transfer station and the highways along Caliente/Las Vegas heavy-haul truck route would transport spent nuclear fuel and high-level radioactive waste through several areas identified as culturally important to Native Americans. In addition, the route passes through approximately 1.6 kilometers (1 mile) of the Las Vegas Paiute Reservation, and the U.S. 93 segment passes near the Moapa Reservation.

6.3.3.2.3.6 Caliente/Las Vegas Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente/Las Vegas route. Impacts from the associated intermodal transfer station in Caliente would be the same as those discussed in Section 6.3.3.2.1.

Highway Construction and Upgrades. Industrial safety impacts on workers from upgrading highways for the Caliente/Las Vegas route would be small (Table 6-105). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities from commuting workers and the

Table 6-105. Impacts to workers from industrial hazards from upgrading highways along the Caliente/Las Vegas route.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	44	200
Lost workday cases	22	110
Fatalities	0.06	0.55
Noninvolved workers[d]		
Total recordable cases	2.6	11
Lost workday cases	1.0	4.3
Fatalities	0.003	0.01
Totals[e]		
Total recordable cases	47	210
Lost workday cases	23	110
Fatalities	0.06	0.56

a. Impacts are totals over about 46 months.
b. Includes impacts from periodic maintenance and resurfacing activities. Impacts are totals over 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

movement of construction materials and equipment. Table 6-106 lists the estimated fatalities from construction and commuter vehicle traffic.

Table 6-106. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente/Las Vegas route for heavy-haul trucks.[a]

Activity	Kilometers[b]	Traffic fatalities	Vehicle emissions fatalities
Construction[c]			
Material delivery vehicles	41,000,000	0.7	0.09
Commuting workers	37,000,000	0.4	0.05
Subtotals	*78,000,000*	*1.1*	*0.13*
Operations[d]			
Commuting workers	200,000,000	2.0	0.26
Totals	***280,000,000***	***3.0***	***0.39***

a. Includes impacts from construction and operations of an intermodal transfer station.
b. To convert kilometers to miles, multiply by 0.62137.
c. Impacts are totals over about 46 months.
d. Impacts are totals over about 24 years.

Operations. Incident-free radiological impacts listed in Table 6-107 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the Caliente/Las Vegas route. These impacts would include those from transportation along the route and along railways in Nevada leading to the Caliente intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-107. Health impacts from incident-free Nevada transportation for the Caliente/Las Vegas route heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	1,400	1,400
Estimated latent cancer fatality	0.02	0.56	0.58
Public			
Collective dose (person-rem)	7	220	230
Estimated latent cancer fatality	0.003	0.11	0.11
Estimated vehicle emission-related fatalities	0.002	0.062	0.064

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

6.3.3.2.3.7 Caliente/Las Vegas Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways along the Caliente/Las Vegas route and building an intermodal transfer station for heavy-haul truck transportation. The discussion includes impacts from the operation of an intermodal transfer station at Caliente and periodic resurfacing of the highways and the planned Las Vegas Beltway.

The analysis of socioeconomic impacts assumed that Clark County would secure a loan to advance the construction schedule of the portion of the Las Vegas Beltway that would be part of the Caliente/Las Vegas route. The analysis based the estimates of impacts on two sources of information from Clark County on the cost of building a section of the Beltway. These sources estimate that modifications to the Northern Beltway would cost between $43.6 million (DIRS 103710-Clark County 1997, p. 2-7) and $463 million (DIRS 155112-Berger 2000, p. 29) (about $43.6 to $463 million in 2001 dollars). DOE believes the actual impact will be between the two values. The loan to Clark County for $43.6 million or $463 million, at a real rate of 3 percent, with repayment of the loan starting in 2010 and lasting for 30 years, is a part of the modeling to determine impacts to employment, population, real disposable income, and expenditures by State and local governments. (A *real* percentage rate is the premium paid in addition to the rate of inflation; a real rate plus the rate of inflation equals the nominal or quoted rate.) Clark County would repay the loan from tax revenues.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading public highways for the Caliente/Las Vegas route, advancing the scheduled completion of a portion of the Las Vegas Beltway, and building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. Employment for highway upgrades, excluding the Beltway, and construction of an intermodal transfer station would be about 832,000 worker-hours or 416 worker-years. The highway upgrades, excluding the Beltway, would cost $96.8 million, would take approximately 46 months, and would occur during the 48-month construction period anticipated for the Beltway. The analysis assumed that if DOE selected this route, Clark County would advance the construction schedule of the Beltway and would reconfigure the design to accommodate use by heavy-haul trucks. Constructing an intermodal transfer station would cost $25 million and require 18 months to complete. (Dollar values reported in this section are 2001 dollars unless otherwise stated.)

This section expresses values for socioeconomic measures (employment, population, real disposable income, Gross Regional Product, and State and local government expenditures) and for the potential impacts of change in those measures as a range of values. The first value refers to the outcome if the Beltway cost is $43.6 million; the second refers to the outcome if the cost is $463 million. DOE anticipates that the actual change would fall between the two values.

Employment

In the region of influence, increased employment of construction workers involved with upgrading the highways (including the Beltway) and with building an intermodal transfer station (direct workers) and other workers employed as a result of the economic activity generated by the project (indirect workers) would peak in 2008 at between 588 and 1,979 persons. The increase in employment in Clark County would be between 544 and 1,910 workers, Nye County would gain between 8 and 29 workers, and Lincoln County would gain between 36 and 40 workers. The increases in Clark and Nye Counties would be less than 1 percent of the employment baseline for each county. The increase in Lincoln County would be less than 2 percent of the County’s employment baseline.

Population

Projected population increases in the region of influence that would result from construction work related to the Caliente/Las Vegas route would peak in 2009. During that year, population would be more than the baseline by between 500 and 2,002 individuals. The change in population for Clark County would be between 477 and 1,943 people, for Lincoln County between 13 and 17 people, and for Nye County between 10 and 42 people. The impacts from an increase in population as a result of increased employment opportunities would be less than 1 percent of each county’s population baseline. Because the increases in population in each county would be so small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Economic measures would rise during the construction of an intermodal transfer station and the upgrading of highways and the Las Vegas Beltway. The increase above the baseline in real disposable income of people in the region of influence would peak in 2008 at between $19.0 million and $65.3 million. The region-wide increase in Gross Regional Product would peak in 2008 at between $33.1 million and $104.1 million. Increased State and local government expenditures resulting from highway upgrades and the intermodal transfer station construction project would peak in 2009 at between $1.7 million and $6.6 million. The Gross Regional Product, real disposal personal income, and expenditures by State and local governments would rise by less than 1 percent in Clark, Nye, and Lincoln Counties. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Caliente/Las Vegas heavy-haul truck route workers and indirect (support) workers would decrease by 516 to 2,123 when construction of the intermodal transfer station and highway upgrades (including the Beltway portion) ended in 2009. Clark County would lose between 506 and 2,087 of these jobs, Nye County would lose between 5 and 27 of these jobs, and Lincoln County would lose between 4 and 9 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Caliente/Las Vegas route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. If DOE selected this route, operations at an intermodal transfer station near the City of Caliente and use of heavy-haul trucks would begin in 2010 and continue until 2033. A workforce of 26 would be required for the intermodal transfer station. Direct employment for heavy-haul truck operations, including escorts, would be 120 workers.

To analyze impacts of operations for a Caliente/Las Vegas heavy-haul truck route, DOE considered three activities: operation of the intermodal transfer station, operation of heavy-haul trucks, and maintenance of highways and the Las Vegas Beltway.

Employment and Population

Employment associated with an intermodal transfer station and heavy-haul trucks would remain relatively level throughout operations. Total employment in the region of influence attributable to operation of a Caliente/Las Vegas route would average about 209 workers. The analysis determined that about 110 workers would come from Clark County, about 11 from Nye County, and 88 from Lincoln County. The impact on population would be about 359 additional residents in the region. About 224 persons would live in Clark County, about 25 in Nye County, and about 110 in Lincoln County. Additional employment and population for Lincoln County, which would experience the largest changes as a percentage of the baselines, would be about 3.3 percent of the employment baseline and 2.3 percent of the population baseline. These impacts would be within the range of historic changes in the county.

During the operational period of heavy-haul truck shipments, periodic road resurfacing would be needed. Employment (direct and indirect) in the region would increase by about 191 workers during the 2-year duration of resurfacing projects. DOE assumed that all the workers would come from Clark County-based employers. Overall, employment increases from periodic (every 8 years starting in 2016) highway resurfacing projects would be less than 1 percent of the baseline for Clark County. Given the short duration of each resurfacing project, there would be no perceptible change in the region's population. Employees hired to resurface the highways and their families are included in the averages discussed below.

The net changes to employment and population from three operational activities associated with a Caliente/Las Vegas route during the 24 years of operations can be summarized. If the cost of the beltway was approximately $43.6 million, there would be an incremental increase of 225 jobs in the region of influence, 119 in Clark County, 13 in Nye County, and 93 in Lincoln County. This impact would be less than 1 percent of the baselines in Clark and Nye Counties, and 3.5 percent of the baseline in Lincoln County. If the cost of the beltway reaches $463 million, employment in the region of influence, while continuing to grow to approximately 1,137,000 positions, would have 108 fewer employment opportunities. Clark County would have 211 fewer positions, but Nye County would gain 10 positions and Lincoln County would gain 93 positions during the operations phase. Impacts to the baselines in Clark and Nye Counties would be less than 1 percent, but the change in Lincoln County would be 3.4 percent of the baseline.

The region of influence would experience a growth in population of an additional 440 residents, 292 in Clark County, 29 in Nye County, and 119 in Lincoln County. This impact would be less than 1 percent of the baselines in Clark and Nye Counties, but 2.5 percent of the baseline in Lincoln County. Because the impacts would be small in Clark and Nye Counties, impacts to housing or schools would be unlikely. The increase in population in Lincoln County would include an annual average of 32 school-age children. There would be no impact in the housing market in Lincoln County given the chronically high vacancy rate in housing (see Chapter 3, Section 3.1.7.4).

Economic Measures

Changes in employment and population would drive changes in economic measures attributable to the project. If the final loan amount was $43.6 million, real disposable income in the region of influence would rise throughout operations, starting at $3.9 million in 2010 and increasing to $14.7 million in 2033. The average would be $8.6 million. Gross Regional Product would also rise during operations; the average annual increase would be $13.4 million. State and local government expenditures would also increase with an average annual increase of $2.3 million. Increases to real disposable income, Gross Regional Product, and government expenditures would be less than 1 percent of the baselines for Clark and Nye Counties. The changes in Lincoln County would be more visible. Changes in real disposable income ($3.0 million annually) and government expenditures for the County would be approximately 2.5 and 3.0 percent of the baselines, respectively. The projected change in Gross Regional Product ($5.6 million annually) for the County would be 3.9 percent of the baseline. These changes would be within the range of historic short-term changes for Lincoln County.

If the final loan amount was $463 million, growth in real disposable income in the region of influence would slow throughout the operations period as the loan is repaid. Starting at $5.3 million above the baseline in 2010 and declining to $26.8 million below the baseline in 2033, growth in real disposable income would decline by an average of $24.2 million, or 0.043 percent of the region of influence's baseline during the operations phase. Real disposable income in Lincoln County would increase by an average of $3.0 million. This change would represent 2.5 percent of the County's baseline. Increases in Gross Regional product would average $468,000 in Nye County and $5.5 million in Lincoln County. The increase in Nye County would be less than 1 percent, but the change represents 3.8 percent of the baseline in Lincoln County. The rate of growth in Gross Regional Product would decline by an average of $12.1 million in Clark County and $6.1 million in the region of influence. These impacts would be less than 1 percent of the applicable baselines. Expenditures by State and local governments attributable to the project would average $100,000 in Nye County and $1.2 million in Lincoln County. The increase in Nye County would be less than 1 percent of the baselines, but the increase in Lincoln County would be 3.0 percent of the baseline. Growth in expenditures by State and local governments would slow by an average of $1.3 million in Clark County, an impact of less than 1 percent of the County's baseline. As population growth slows, there would also be a slowing in the rate of tax revenue collected and a slowing in the rate of population growth that would require a given level of public services.

In addition, DOE analyzed a sensitivity case in which all Lincoln County socioeconomic impacts were assumed to occur only in the City of Caliente. Under this assumption, city population would rise by 3 percent during construction and by about 8.7 percent during operations. Employment would rise by about 11 percent during construction and about 12 percent during operations.

6.3.3.2.3.8 Caliente/Las Vegas Route Noise and Vibration

Section 6.3.3.1 discusses noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on the noise impacts that would be unique to the Caliente/Las Vegas heavy-haul truck implementing alternative.

Noise impacts of the Caliente intermodal transfer station would be the same as those discussed in Section 6.3.3.2.1.

Highway Construction and Upgrades. Construction activities for upgrading highways along the Caliente/Las Vegas route would occur on all sections with the exception of the section of I-15 between its intersection with U.S. 93 and the planned North Las Vegas Beltway. North Las Vegas, the Towns of Caliente and Indian Springs, and the small rural communities of Crystal Springs, Ash Springs, and Alamo would fall within the 2,000-meter (6,600-foot) region of influence for construction noise. The potential number of inhabitants would be highest near the greater Las Vegas area. There are scattered residences along U.S. 93 in the Pahranagat Valley.

Because the shipments would pass through a large population area, there would be a potential for noise impacts along the route.

Operations. The Caliente/Las Vegas route would by pass mostly rural communities, and would be confined to established highway systems. Three public schools in Alamo are in the region of influence along U.S. 93 and the Indian Springs school is in the region of influence along U.S. 95. However, the incremental noise increase due to the infrequent heavy-haul truck shipments would not alter the existing noise environment. Because the proposed intermodal transfer station would be on the western edge of Caliente and traffic would not travel through the city, traffic noise impacts in Caliente would be inconsequential. Estimated noise levels (1-hour average sound levels) in Crystal Springs, Ash Springs, Alamo, Indian Springs and Cactus Springs would increase by 0.3 to 2.0 dBA due to heavy-haul truck traffic. A potential *receptor* is the public school in Indian Springs, which also serves students from Cactus Springs. The Indian Springs school is about 300 meters (980 feet) south of U.S. 95. The incremental contribution of heavy-haul trucks at this distance from the highway would not be perceptible. Background traffic noise levels would be greatest along I-15 and the North Las Vegas Beltway, reducing the potential for heavy-haul truck noise to produce adverse effects to public receptors during daylight hours. No historic buildings would be affected by ground vibration. No sensitive ruins of cultural significance have been identified along this route.

On the Caliente/Las Vegas heavy-haul truck route, U.S. 93 passes within 5 kilometers (3 miles) of the Moapa Reservation. However, the distance from the highway to the reservation makes noise impacts unlikely. The estimated mean 1-hour increase in traffic noise due to heavy-haul trucks in this area would be 0.1 dBA over existing background traffic noise (DIRS 155825-Poston 2001, all). This increase would not be perceptible on the reservation. The heavy-haul truck route on U.S. 95 passes through about 1.6 kilometer (1 mile) of the Las Vegas Paiute Reservation. Because of the relatively large traffic volume on U.S. 95, the increase in traffic noise due to heavy-haul trucks in this area would not be perceptible (DIRS 155825-Poston 2001, all).

6.3.3.2.3.9 Caliente/Las Vegas Route Aesthetics

The Caliente intermodal transfer station would be near the entrance to Kershaw-Ryan State Park. Park visitors would receive short-term visual impacts from construction activities. In addition, park visitors could be affected by noise from construction activities that could lessen their recreational experience. These short-term impacts would exist only during construction.

During operation of the intermodal transfer station, noise and lighting probably would be discernible from Kershaw-Ryan State Park, especially during night operations, and would probably detract from the recreational experience. The use of shielded and directional lighting would limit the amount of viewable light from outside the facility operational area.

6.3.3.2.3.10 Caliente/Las Vegas Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Caliente/Las Vegas heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Caliente intermodal transfer station would produce the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

Table 6-108 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Caliente/Las Vegas route. These quantities would be unlikely to be large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-108. Utilities, energy, and materials required for upgrades along the Caliente/Las Vegas route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente-Las Vegas	377	5.5	110	0.55	0.80	21

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.4 *Sloan/Jean Route Implementing Alternative*

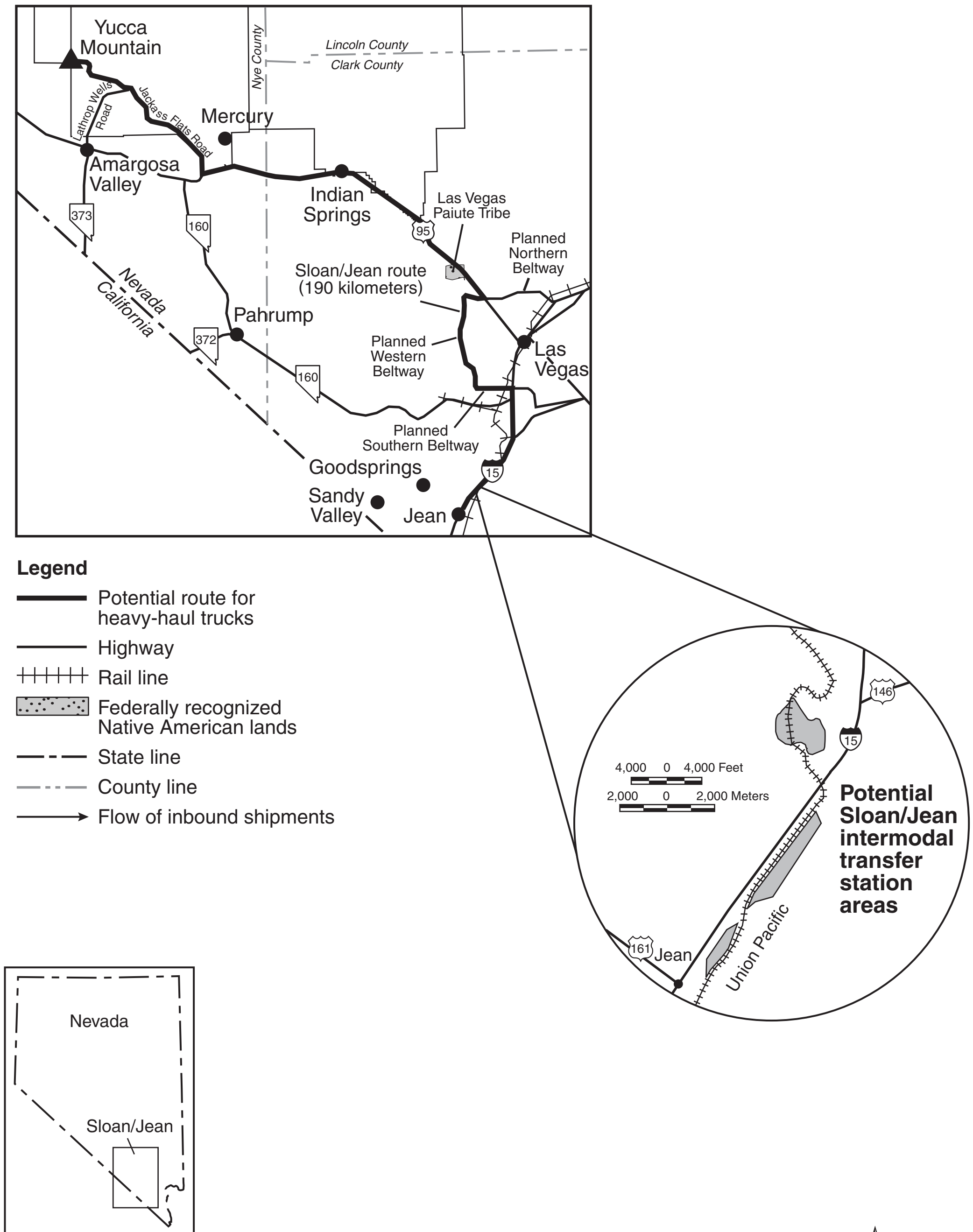
The Sloan/Jean route (Figure 6-25) is about 188 kilometers (117 miles) long. Heavy-haul trucks and escorts leaving a Sloan/Jean intermodal transfer station would enter I-15 at the Sloan interchange. The trucks would travel on I-15 to the exit to the southern portion of the proposed Las Vegas Beltway, and then travel northwest on the beltway. They would leave the beltway at U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. The travel time (vehicle in motion plus periodic short stops for inspections) associated with a Sloan/Jean route would be as much as 4 hours.

The three potential areas for an intermodal transfer station southwest of Las Vegas are between the existing Union Pacific sidings at Sloan and Jean. One area is on the east side of I-15, south of the Union Pacific rail underpass at I-15, and has an area of 3.3 square kilometers (811 acres). The second, which has an area of 3.1 square kilometers (758 acres), is south of the Sloan rail siding along the east side of the rail line. A third area is south of the second, directly north of the Jean interchange on I-15, and has an area of 1.0 square kilometer (257 acres). The estimated life-cycle cost of constructing and operating an intermodal transfer station and of operating heavy-haul trucks along the Sloan/Jean route would be about $444 million in 2001 dollars.

The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to aesthetics and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.2.4.1 Sloan/Jean Route Land Use and Ownership

This section describes anticipated land-use impacts that could occur from the construction and operation of the Sloan/Jean intermodal transfer station, upgrades of highways, and heavy-haul truck operations over



Potential heavy-haul truck routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative and additional preferred routes as specified in 49 CFR 397.103, that could include routes other than ones through the Las Vegas metropolitan area.

To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104588-YMP (1998, all).

Figure 6-25. Sloan/Jean heavy-haul truck route.

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the Sloan/Jean route. Chapter 3, Section 3.2.2.2.1, describes the Sloan/Jean intermodal transfer station site and the associated truck route.

Highway Construction and Upgrades. At the Sloan/Jean intermodal station area there could be potential impacts related to the current use of the land. All three Sloan/Jean candidate sites are on land administered by the Bureau of Land Management. The northernmost area is in the Spring Mountain grazing allotment and the Ivanpah Valley desert tortoise area of critical environmental concern. The Bureau of Land Management has designated land east of the railroad as a gravel pit (community pit), but that land has not been worked; the area is open to fluid mineral leasing but closed to mining claims. The two southern areas are in the Jean Lake grazing allotment, a special recreation management area, and an area designated as available for sale or transfer. Both southern areas are open to fluid mineral leasing and mining claims (DIRS 104993-CRWMS M&O 1999, p. 21).

This route would require the disturbance of approximately 0.63 square kilometer (160 acres) of land from road upgrades and additional construction activities. Table 6-109 summarizes these disturbances.

The land under consideration would require a change in ownership from the Bureau of Land Management to DOE. The amount of land transferred from grazing lands to DOE would result in a small loss to the allotment. Because of the relatively small size of the required parcels and their proximity to roads and railways, the removal of these lands would be unlikely to affect livestock management. A potential loss of desert tortoise habit is discussed below. The amount of land that would be removed from fluid mineral leases is small and would be unlikely to cause long-term impacts. If the areas under consideration were already under lease, DOE would negotiate a transfer with the lessee.

Table 6-109. Land disturbances along the Sloan-Jean heavy-haul truck route.

Disturbance	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	0.47
Aggregate plants	0.08
Road widening	<0.01
Passing lanes	None
Truck turnouts	None
Fortymile Wash new road	0.04
Overnight stops	None
Mercury turnoff road	0.03
Total disturbed area	0.63

a. Numbers approximate due to rounding.
b. To convert square kilometers to acres, multiply by 247.1.

The removal of land from a special recreational management area would be unlikely to cause long-term impacts to recreational activities. The Bureau of Land Management could make other lands available for the recreational activities. This would require agreement between the Bureau and DOE before the start of construction activities.

The potential loss of lands from the Bureau of Land Management land sale/transfer program could cause a loss of potential tax revenue.

The Sloan/Jean route would require considerable improvements at the interchange with I-15. A small amount of land would be converted for the improvements. Section 6.3.3.1 discusses other impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

Operations. There would be no direct land-use impacts associated with the operation of the Sloan/Jean intermodal transfer station or the Sloan/Jean route other than those described in Section 6.3.3.1.

6.3.3.2.4.2 Sloan/Jean Route Air Quality

This section describes anticipated nonradiological air quality impacts from construction activities and operations of an intermodal transfer station, highway construction and upgrades, and operation of heavy-haul trucks along the Sloan/Jean route. Such impacts would result from releases of criteria pollutants, including nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10}) (see Section 6.3.3.1).

Carbon monoxide and PM_{10} are of particular interest along the Sloan/Jean route because some construction activities as well as heavy-haul truck transport would occur through the Las Vegas Basin, which is classified as a serious nonattainment area for those pollutants, and because the intermodal transfer station locations would be in or near the nonattainment area. PM_{10} and carbon monoxide emissions from intermodal transfer station construction are presented in Section 6.3.3.1. Intermodal transfer station construction emissions would be 15 percent of the PM_{10} General Conformity threshold and would be 2.3 percent of the carbon monoxide General Conformity threshold level.

Highway Construction and Upgrades. Section 6.3.3.1 discusses the methods used to estimate the air quality impacts for the construction activities for the Sloan/Jean route. PM_{10} emissions would be an estimated 41 metric tons (45 tons) per year, including estimated emissions for the accelerated construction activities of the southern and western portions of the Las Vegas Beltway. These emissions would be 64 percent of the General Conformity threshold level. Carbon monoxide emissions for highway construction and upgrades would be an estimated 33 metric tons (36 tons) per year. These emissions are 36 percent of the carbon monoxide General Conformity threshold level.

Operations. Section 6.3.3.1 discusses the air quality impacts associated with the operation of a locomotive at the Sloan/Jean intermodal transfer station. In addition to these operations, the operation of heavy-haul trucks along the Sloan/Jean route would affect the Las Vegas Valley air basin. Air quality impacts from heavy-haul trucks to this air basin would be small [0.62 metric tons (0.68 ton) per year of carbon monoxide] with emissions at less than 1 percent of the General Conformity threshold level. These emissions would result from 11 round trip heavy-haul trucks traveling through the Las Vegas Valley each week.

6.3.3.2.4.3 Sloan/Jean Route Hydrology

DOE anticipates limited impacts to surface water and groundwater during upgrades to Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these impacts as well as those from the construction and operation of an intermodal transfer station and operation of trucks on the Sloan/Jean route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all of the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

Surface Water

Section 6.3.3.1 discusses the impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed in Section 6.3.3.1 apply to surface water along the Sloan/Jean route.

The assessment in Appendix L compares what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.8 and L.4.2.2). The southernmost of the three locations for the Sloan/Jean station appears to be, at least in part, in a 100-year flood zone of a normally dry drainage channel (see Section L.3.2.8).

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Upgrades to the Sloan/Jean route would not require any water wells. The road upgrades would require an estimated total of about 9,200 cubic meters (8 acre-feet) of water (DIRS 104917-LeFever 1998, all). Options for obtaining this water would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (about 500 truckloads) to construction sites, or use a combination of these two actions.

Operations. Section 6.3.3.1 discusses impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck routes.

6.3.3.2.4.4 Sloan/Jean Route Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer stations and routes. This section discusses the construction- and operations-related impacts that would be unique to the Sloan/Jean intermodal station and route.

Highway Construction and Upgrades. Potential Sloan/Jean intermodal transfer station site locations are between the existing Union Pacific rail sidings at Sloan and Jean. The dominant land cover type in these areas is creosote-bursage (DIRS 104593-CRWMS M&O 1999, p. 3-36). The land cover type at the site is extensive in the region (DIRS 104593-CRWMS M&O, pp. C1 to C5).

The three sites that DOE is considering for a Sloan/Jean intermodal transfer station are in the range of the desert tortoise, but none of the areas are critical habitat for the tortoise (50 CFR 17.95). The construction site would disturb approximately 0.2 square kilometer (50 acres) of tortoise habitat. The likelihood of tortoise death or injury due to construction activities would be small if DOE moved tortoises in the immediate area to a safe habitat. The pinto beardtongue (classed as sensitive by the Bureau of Land Management) occurs in two of the proposed locations of the Sloan/Jean intermodal transfer station (DIRS 104593-CRWMS M&O 1999, p. 3-36). If one of these sites was selected, DOE would conduct pre-activity surveys for this plant species and would avoid disturbance of occupied areas if possible. The construction of an intermodal transfer station at a site southwest of Sloan could cause bighorn sheep to avoid the eastern edge of their winter range in that area. There are no springs or other areas that could be classified as wetlands at the location of the intermodal transfer station (DIRS 104593-CRWMS M&O 1999, p. 3-36).

Predominant land cover types in nonurban areas along the route are creosote-bursage and Mojave mixed scrub (DIRS 104593-CRWMS M&O 1999, p. 3-36). The regional area for each vegetation type is extensive. Because areas disturbed by upgrade activities would be in or adjacent to existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

The only threatened or endangered species that occurs along the route is the desert tortoise. Desert tortoise habitat occurs throughout the length of the route (DIRS 103160-Bury and Germano 1994, pp. 57 to 72; 50 CFR 17.95). Construction activities could kill or injure desert tortoises; however, losses would be few because construction would occur only on the right-of-way and desert tortoises are uncommon along heavily traveled roads (DIRS 103160-Bury and Germano 1994, Appendix D, p. D12). Four other special status species occur along this route (DIRS 104593-CRWMS M&O 1999, p. 3-36), but construction activities would be limited to the road and adjacent areas; occupied habitat would not be destroyed and these species should not be affected.

This route would not cross any areas designated as game habitat and there are no springs or wetlands near the route. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and obtain individual or regional permits, as appropriate (DIRS 104593-CRWMS M&O 1999, p. 3-36). Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

6.3.3.2.4.5 Sloan/Jean Route Cultural Resources

Highway Construction and Upgrades. A total of 59 archaeological and historic sites have been recorded along existing highway rights-of-way along the Sloan/Jean heavy-haul truck route (DIRS 155826-Nickens and Hartwell 2001, Appendix A). None of these occur in areas along roads that would require upgrades.

There are seven archaeological sites near the location of the Sloan/Jean intermodal transfer station, none of which has been evaluated for potential eligibility for the *National Register of Historic Places* (DIRS 155826-Nickens and Hartwell 2001, Appendix A). Possible unrecorded sites in the intermodal transfer station location include some associated with the original construction of the railroad in the early part of the 20th century, such as construction camps. The location of the "Last Spike," where the last two segments of the railroad were joined occurs in the vicinity of the site.

No areas or sites of cultural importance to Native Americans have been identified along the Sloan/Jean route or at the intermodal transfer station location, although field studies have not been completed. The route follows a portion of U.S. 95 that passes though approximately 1.6 kilometers (1 mile) of the Las Vegas Paiute Reservation.

Operations. Based on currently available information, operation of a Sloan/Jean intermodal transfer station and heavy-haul truck route would have no impacts on cultural resources.

6.3.3.2.4.6 Sloan/Jean Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Sloan/Jean route. Impacts from the associated intermodal transfer station in the Sloan/Jean area would be the same as those discussed in Section 6.3.3.1.

Highway Construction and Upgrades. Industrial safety impacts on workers from upgrading highways for the Sloan/Jean route would be small (Table 6-110). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-111 lists the estimated fatalities from construction and commuter vehicle traffic.

Operations. The incident-free radiological impacts listed in Table 6-112 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the Sloan/Jean route. These impacts would include transportation along the Sloan/Jean route as well as transportation along railways in Nevada leading to the Sloan/Jean intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-110. Health impacts to workers from industrial hazards from upgrading highways along the Sloan/Jean route.

Group and industrial impact category	Construction[a]	Operations[b]
nvolved workers		
Total recordable cases[c]	23	120
Lost workday cases	11	66
Fatalities	0.032	0.33
Noninvolved workers[d]		
Total recordable cases	1.4	6.8
Lost workday cases	0.5	2.5
Fatalities	0.001	0.007
otals[e]		
Total recordable cases	24	130
Lost workday cases	12	68
Fatalities	0.033	0.34

a. Impacts are totals over about 48 months.
b. Includes impacts for periodic maintenance and resurfacing. Impacts are totals over about 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Table 6-111. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Sloan/Jean route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	17,000,000	0.3	0.04
Commuting workers	21,000,000	0.2	0.03
Subtotals	*38,000,000*	*0.5*	*0.06*
Operations[c]			
Commuting workers	120,000,000	1.2	0.16
Totals	*170,000,000*	*1.7*	*0.23*

a. Includes impacts of construction and operation of an intermodal transfer station.
b. To convert kilometers to miles, multiply by 0.62137.
c. Impacts are totals over about 48 months.
d. Impacts are totals over 24 years.

Table 6-112. Health impacts from incident-free Nevada transportation for the Sloan/Jean heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	38	1,200	1,200
Estimated latent cancer fatalities	0.02	0.48	0.50
Public			
Collective dose (person-rem)	7	330	340
Estimated latent cancer fatalities	0.003	0.17	0.17
Estimated vehicle emission-related fatalities	0.002	0.19	0.19

a. Impacts are totals for 24 years.
b. Includes impacts to workers at an intermodal transfer station.
c. Totals might differ from sums of values due to rounding.

6.3.3.2.4.7 Sloan/Jean Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways along the Sloan/Jean route, constructing and modifying a section of the planned Las Vegas Beltway, and building an intermodal transfer station for heavy-haul truck transportation. The discussion includes the impacts of operating an intermodal transfer station near Sloan/Jean in Clark County and of periodic resurfacing of the highways and Beltway.

This analysis of socioeconomic impacts assumed that Clark County would secure a loan to advance the construction schedule of the portion of the Las Vegas Beltway that would be part of this heavy-haul truck route. DOE estimates that modifications to the Beltway would cost between $98.1 million and $790 million in 2001 dollars. DOE believes the actual impacts would be between the two values. A loan to Clark County for $98.1 or $790 million, at a real rate of 3 percent, with repayment of the loan starting in 2010 and lasting for 30 years, is a part of the modeling to determine the impacts to employment, population, real disposable income, and expenditures by State and local governments. (A *real* percentage rate is the premium paid in addition to the rate of inflation; a real rate plus the rate of inflation equals the nominal or quoted rate.) Clark County would repay the load from tax revenues. DOE assumes most repayment funds would be from sources the county has already identified for completion of the Beltway.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading existing highways for a Sloan/Jean route, advancing the construction schedule for modifying a portion of the planned Las Vegas Beltway, and building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. Upgrading the existing highways for the route, excluding the Beltway, would cost about $20.8 million and would require 48 months to complete. The upgrades to the highways would occur during the 48-month construction period for the planned portion of the Beltway. Building an intermodal transfer station would cost $25 million and would require 18 months. If DOE selected this route, the Beltway construction schedule would be advanced to accommodate use by heavy-haul trucks. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Employment

The dynamics of specific construction projects include a period of brief, intense elevation in project-related employment, followed by an abrupt decrease in associated employment opportunities as construction workers move to other projects. Composite employment would peak in the region of influence in 2008, would be approximately 631 workers under the $98.1 million beltway assumption, and would peak in 2006 at 3,047 workers under the estimated $790 million assumption. Under the entire range of estimated costs, Clark County would provide more than 96 percent of the workers. Clark County would gain 620 to 2,996 workers, Nye County would gain 9 to 42 workers, and Lincoln County would gain 2 to 9 workers. The change in employment for Clark, Nye, and Lincoln Counties would be less than 1 percent of their employment bases.

Population

Population increases in the region of influence due to a Sloan/Jean route and intermodal transfer station construction would peak in 2009. During that year, the incremental increase in population for Clark County would be between 532 and 2,951 people, for Lincoln County between 1 and 8 people, and for Nye County between 11 and 63 people. The impacts due to an increase in population as a result of increased employment opportunities would be less than 1 percent of each county's population baseline. Because the increases in population in each county would be small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Economic measures would rise during the construction of an intermodal transfer station, upgrading of highways, and construction of the Las Vegas Beltway. The increase in real disposable income of people in the three-county region of influence would peak in 2008 at between $20.7 million and $97.3 million. The region-wide increase in Gross Regional Product would peak in 2008 at between $36.0 million and $153.2 million. Increased State and local government expenditures would peak in 2009 at between $1.8 million and $9.9 million. The Gross Regional Product, real disposal personal income, and expenditures by State and local governments would rise by less than 1 percent of the baselines in Clark, Nye, and Lincoln Counties. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Sloan/Jean heavy-haul route workers and indirect (support) workers would decrease by 588 to 3,240 when construction of the intermodal transfer station and highway upgrades (including the Beltway portion) ended in 2009. Clark County would lose between 579 and 3,185 of these jobs, Nye County would lose between 8 and 45 of these jobs, and Lincoln County would lose between 1 and 10 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Sloan/Jean route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. Operations at an intermodal transfer station near Sloan/Jean and the use of heavy-haul trucks would begin in 2010 and last until 2033. A workforce of about 26 would be required for the intermodal transfer station. Direct employment for heavy-haul truck operations over a Sloan/Jean route, including shipment escorts, would be about 66 workers. The analysis assumed that operations workers would reside in Clark County.

To analyze the impacts of using a Sloan/Jean route for heavy-haul trucks, DOE considered three activities: the operation of the intermodal transfer station, the operation of heavy-haul trucks, and the maintenance of the highways and the Las Vegas Beltway.

Employment and Population

Employment associated with the operations of an intermodal transfer station and heavy-haul trucks would remain relatively level throughout operations. Total employment in the region of influence attributable to a Sloan/Jean route would average about 107 workers. The analysis determined that about 99 workers would come from Clark County and that the other 8 would come from outside the three-county region of influence. The impact on the population from operating heavy-haul trucks and the intermodal transfer station would be about 129 additional residents in the region. About 127 persons would live in Clark County, and 2 people would live in Nye County. Lincoln County would be unlikely to gain population as a result of this project. Impacts to the employment and population baselines in Nye and Clark Counties would be less than 1 percent. Because the incremental increase in population would be so small, impacts to housing and the school system would be unlikely.

Because of the periodic need to resurface highways used by heavy-haul trucks, construction maintenance employment would increase in the years during which these projects occurred. Resurfacing would occur from 2016 to 2017, 2024 to 2025, and 2032 to 2033. During these years, total employment in the region of influence would increase by about 42 jobs and decline as maintenance activities ended. DOE assumed that virtually all of the resurfacing construction employees would come from Clark County employers. Employment changes from periodic (every 8 years) highway-resurfacing projects would be less than 1 percent of the employment baseline in Clark County. The employees who would resurface the roads and their families are included in the employment and population averages discussed above for the operations phase.

Net changes to employment and population from all three portions of the Sloan/Jean heavy-haul truck route during the 24-year operations phase can be summarized. There would be an incremental average annual increase of 48 positions in the region of influence, 47 of them in Clark County if the cost of the beltway was approximately $98.1 million. The region of influence would experience a growth in population of 53 additional residents, 48 in Clark County and 5 in Nye County. These impacts would be less than 1 percent of the baselines. If the cost of the beltway reaches $790 million, the region of influence, while continuing to grow to an average of 1.1 million jobs, would have 501 fewer employment positions. Approximately 497 of these positions would have been in Clark County. Population, which is driven by employment opportunities, would be affected. The region of influence (with an average of 2.29 million residents) would have 1,016 fewer residents, all of whom would have lived in Clark County. Impacts to populations and employment at the upper range of the cost estimates would be less than 1 percent of the baselines.

Economic Measures

Changes in employment and population would drive changes in economic measures attributable to the project. If the final loan amount was $98.1 million, real disposable income in the region of influence would oscillate above and below the baseline throughout the operations period. The average would be $616,000 below the region of influence's $55.7 million average baseline. Gross Regional Product would rise during operations, with the average increase being $5.8 million. Annual State and local government expenditures would increase, with the average increase being $176,000. Increases to real disposable income, Gross Regional Product, and government expenditures would be less than 1 percent of the baselines for Clark, Nye, and Lincoln Counties.

If the final loan amount was $790 million, impacts would be more visible, but still less than 1 percent of the economic measure baselines for each county. Growth in real disposable income in the region of influence would slow throughout the operations period as the loan is repaid. Growth in real disposable income would decline by an average of $54.7 million, or 0.0981 percent of the region of influence's baseline during the operations phase. Decreases in Gross Regional Product would average $26.3 million in the three-county region of influence. The decline in the growth rate would be less than 1 percent of each county's baseline. A slowing in expenditures by State and local governments attributable to the project would average $3.7 million annually region-wide. As population growth slowed, there would be slowing in the rate of tax revenue collected and a slowing in the rate of population growth that would require a given level of public services.

6.3.3.2.4.8 Sloan/Jean Route Noise and Vibration

Section 6.3.3.1 discusses noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on the noise impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

Highway Construction and Upgrades. There are residences and commercial businesses near the three potential sites for an intermodal transfer station in the Sloan/Jean area. Construction noise would occur during daylight hours and would be a temporary source of elevated noise in the area. Nighttime noise impacts would be unlikely because construction activities would not occur at night.

For the Sloan/Jean route, southern and western Las Vegas, the Town of Indian Springs, and the small rural community of Jean would be within the 2,000-meter (6,600-foot) region of influence for construction noise. Construction activities would occur on all sections of the route with the exception of I-15 between its interchange at Sloan and the planned Southern Las Vegas Beltway. Because the number of inhabitants of the region of influence would be high because the route passes around the greater Las Vegas area and includes other small rural communities and towns, there is a potential for construction noise impacts.

Operations. The presence of residences and commercial businesses near the Sloan/Jean location would make an intermodal transfer station a potential source of more noise complaints than the more remote locations. However, because operational noise in the vicinity of Sloan/Jean would not be much higher than the levels associated with most other light industrial areas, noise impacts would be unlikely. Railcar switching would be the greatest source of noise.

The Sloan/Jean route would use established highway systems with wide shoulders. The incremental noise increase due to the infrequent heavy-haul truck shipments would not alter the existing noise environment. Estimated noise levels (1-hour average sound levels) at Indian Springs and Cactus Springs would increase by about 0.4 dBA [at 15 meters (50 feet) from the road] due to heavy-haul truck traffic. Background traffic noise levels would be greatest along the western Beltway, reducing the potential for heavy-haul truck noise to cause adverse effects to public receptors during daylight hours. A potential receptor is the public school in Indian Springs which also serves students from Cactus Springs. The Indian Springs school is about 300 meters (980 feet) south of U.S. 95. The incremental contribution of heavy-haul trucks at this distance from the highway would not be perceptible. No historic buildings would be affected by ground vibration. No sensitive ruins of cultural significance have been identified along this route.

The Sloan/Jean heavy-haul truck route on U.S. 95 passes through about 1.6 kilometer (1 mile) of the Las Vegas Paiute Reservation. Because of the relatively large traffic volume on U.S. 95, the increase in traffic noise due to heavy-haul trucks in this area would not be perceptible (DIRS 155825-Poston 2001, all).

6.3.3.2.4.9 Sloan/Jean Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

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Highway Construction and Upgrades. The construction of the Sloan/Jean intermodal transfer station would have the same utilities, energy and materials impacts as those discussed in Section 6.3.3.1.

Table 6-113 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Sloan/Jean route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-113. Utilities, energy, and materials required for upgrades along the Sloan/Jean route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Sloan/Jean	188	1.7	27	0.24	0.1	2.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses utilities, energy, and materials needs for operation of an intermodal transfer station.

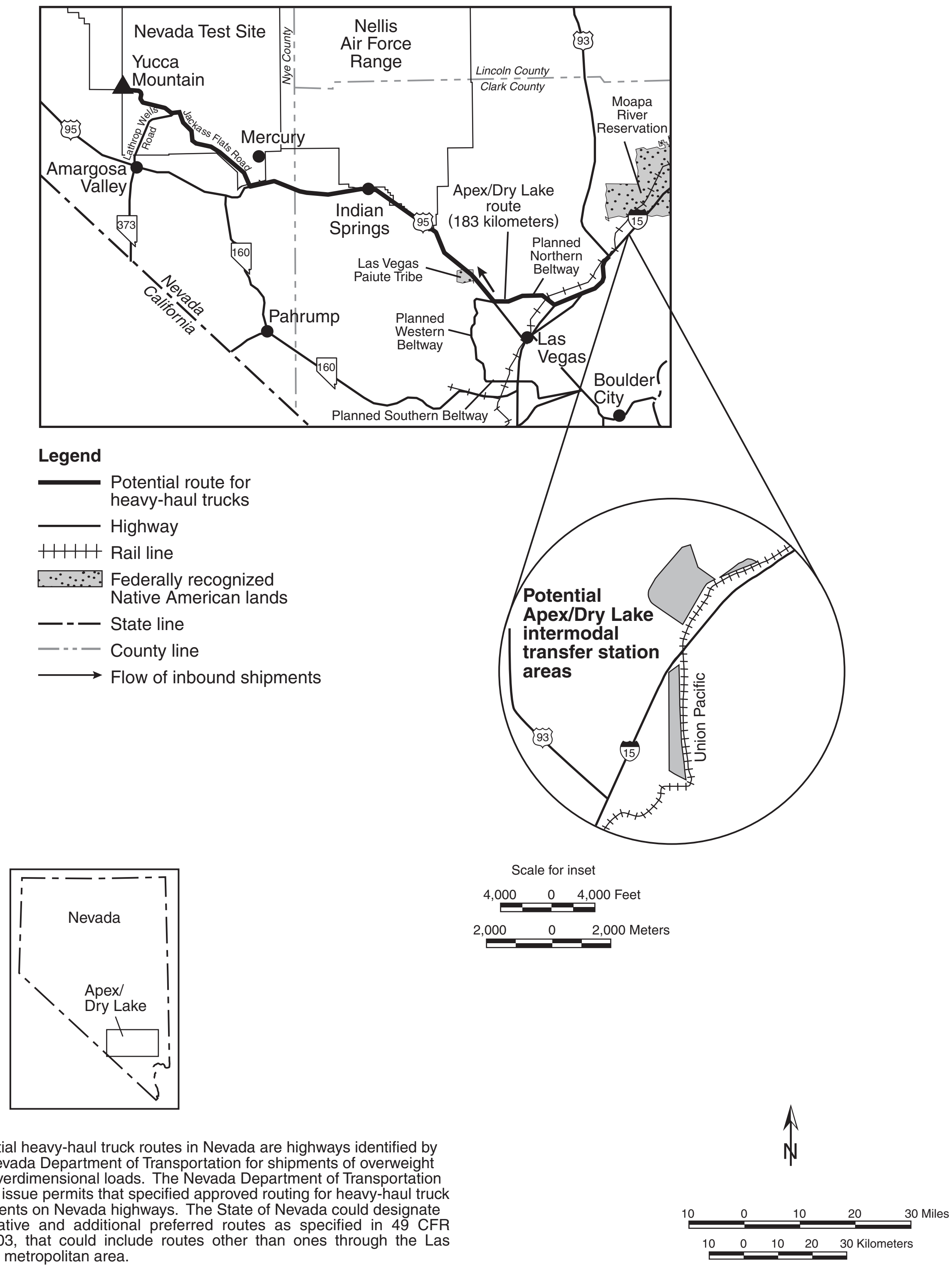
Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.5 *Apex/Dry Lake Route Implementing Alternative*

The Apex/Dry Lake route (Figure 6-26) is about 183 kilometers (114 miles) long. Heavy-haul trucks and escorts would leave the intermodal transfer station at the Apex/Dry Lake location and enter I-15 at the Apex interchange. The trucks would travel south on I-15 to the exit to the proposed northern Las Vegas Beltway and travel west on the Beltway. They would leave the Beltway at U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. The travel time (vehicle in motion plus periodic short stops for inspections) associated with an Apex/Dry Lake route would be as much as 4 hours.

The potential sites for the Apex/Dry Lake intermodal transfer station are in areas northeast of Las Vegas between the Union Pacific rail sidings at Dry Lake and at Apex. Three areas are available for station siting (see Figure 6-26). The first area is directly adjacent to the Dry Lake siding. This area is large [3.5 square kilometers (880 acres)] and has flat topography; it is adjacent to and west of the Union Pacific line. The second is a smaller area [0.18 square kilometer (45 acres)] on the same side of the Union Pacific mainline, a short distance northeast of the 3.5-square-kilometer area, and also has flat topography. This area would be used in combination with a portion of the first area. These two areas are bounded by hills to the north and by a wash and private land to the south. The third area, which is east of I-15, is adjacent to and west of the Union Pacific line and south of where the line crosses I-15. This location has an area of 0.96 square kilometer (240 acres). Because this area is between the Dry Lake and Apex sidings, the construction of an additional rail siding would be necessary. The estimated life-cycle cost to build and operate an intermodal transfer station and to operate heavy-haul trucks along the Apex/Dry Lake route would be about $387 million in 2001 dollars.

The following sections address impacts that would occur to land use; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts to hydrology from the construction and operation of an intermodal transfer station, upgrading of highways, and operation of heavy-haul trucks on an Apex/Dry Lake route would be the same as those discussed in Section 6.3.3.2.4 for a Sloan/Jean route.



Potential heavy-haul truck routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative and additional preferred routes as specified in 49 CFR 397.103, that could include routes other than ones through the Las Vegas metropolitan area.

To convert kilometers to miles, mulitiply by 0.62137.

Source: Modified from DIRS 104588-YMP (1998, all).

Figure 6-26. Apex/Dry Lake heavy-haul truck route.

Impacts to aesthetics and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.2.5.1 Apex/Dry Lake Route Land Use and Ownership

This section describes estimated land-use impacts that could occur from the construction and operation of the Apex/Dry Lake intermodal transfer station, upgrades of highways, and heavy-haul truck operations on the Apex/Dry Lake route. Chapter 3, Section 3.2.2.2.1, describes the Apex/Dry Lake intermodal transfer station site and associated truck route.

Highway Construction and Upgrades. The Apex/Dry Lake intermodal transfer station site could have potential impacts related to the current use of the land. The southern intermodal transfer station parcel east of I-15 at the Apex/Dry Lake site is on land administered by the Bureau of Land Management. Transfer of the property to DOE would be necessary. The northern areas have several infrastructure corridors (power line, telephone, and road rights-of-way). Right-of-way access through these areas would have to be leased by, purchased by, or transferred to DOE. The northern parcels are in the Dry Lake grazing allotment and a planned utility corridor. It is also open to mineral leasing and mining claims. One area has been designated as available for sale or transfer. This site also is in the area of the Apex Industrial Park that began development in mid-1999.

The parcel in the grazing allotment would lose a small parcel of land, if chosen. However, due to the proximity of the parcel to existing roads and rail lines, the transfer of this land to DOE would not divide the grazing allotment and would cause no livestock movement or watering problems.

The relatively small area of an intermodal transfer station location would not create long-term impacts to mineral exploration or mining claims unless the lands are already leased. If there were leases, DOE would negotiate with the lease holders for use of the property.

Because the transfer station parcels are in an area designated for sale or transfer by the Bureau of Land Management, the Bureau would have to remove the lands from this program to transfer them to DOE. The removal of these lands from the sale/transfer program could affect private, municipal or county, or other stakeholders. Tax revenue could be lost through the loss of economic development. This impact could be mitigated by the replacement of removed land with other parcels with similar characteristics. This route would require the disturbance of 0.63 square kilometer (155 acres) of land for road upgrades and additional construction activities. Table 6-114 summarizes these disturbances.

The Apex/Dry Lake route would require considerable improvements at the interchange at I-15. A small amount of land would be converted for the improvements. Section 6.3.3.1 discusses impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

Operations. There would be no direct land-use impacts associated with the operation of the Apex/Dry Lake intermodal transfer station or the Apex/Dry Lake route other than those described in Section 6.3.3.1.

Table 6-114. Land disturbances along the Apex/Dry Lake heavy-haul truck route.

Disturbances	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	0.47
Aggregate plants	0.08
Road widening	None
Passing lanes	None
Truck turnouts	None
Fortymile Wash new road	0.04
Overnight stops	None
Mercury turnoff road	0.03
Total disturbed area	0.63

a. Numbers approximate due to rounding.
b. To convert square kilometers to acres, multiply by 247.1.

6.3.3.2.5.2 Apex/Dry Lake Route Air Quality

This section describes anticipated nonradiological air quality impacts from the construction and operation of an intermodal transfer station, highway construction and upgrades, and operation of heavy-haul trucks along the Apex/Dry Lake route. Such impacts would result from releases of criteria pollutants, nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10}) (see Section 6.3.3.1). Carbon monoxide and PM_{10} are of particular interest along the Apex/Dry Lake Route because heavy-haul truck transport would occur through the Las Vegas Basin, which is classified as a nonattainment area for these pollutants. PM_{10} and carbon monoxide emissions from intermodal transfer station construction are presented in Section 6.3.3.1. Intermodal transfer station construction emissions would be 15 percent of the PM_{10} General Conformity threshold level and would be 2.3 percent of the carbon monoxide General Conformity threshold level.

Highway Construction and Upgrades. Section 6.3.3.1 discusses the methods used to estimate air quality impacts from the construction activities for the Apex/Dry Lake route. PM_{10} emissions would be an estimated 45 metric tons (50 tons) per year, including estimated emissions for the accelerated construction activities of the northern portion of the Las Vegas Beltway. These emissions would be 71 percent of the General Conformity threshold level. Carbon monoxide emissions for highway construction and upgrades would be an estimated 35 metric tons (39 tons) per year. These emissions are 39 percent of the carbon monoxide General Conformity threshold level.

Operations. The air quality impacts for the operations of an intermodal transfer station locomotive at the Apex/Dry Lake intermodal transfer station would be identical to those described for the Sloan/Jean station (see Section 6.3.3.2.4). In addition, heavy-haul trucks would pass through the Las Vegas Valley air basin. The air quality impacts from the heavy-haul trucks to this air basin would be small [0.46 metric tons (0.51 ton] per year carbon monoxide) with emissions at less than 1 percent of the General Conformity threshold level. These emissions would result from 11 roundtrip heavy-haul trucks traveling through the Las Vegas Valley each week.

6.3.3.2.5.3 Apex/Dry Lake Route Hydrology

DOE anticipates limited impacts to surface water and groundwater during upgrades to Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these impacts as well as those from the construction and operation of an intermodal transfer station and operation of trucks on the Apex/Dry Lake route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all of the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Apex/Dry Lake heavy-haul truck implementing alternative.

Surface Water

Section 6.3.3.1 discusses the impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed in that section apply to surface water along the Sloan/Jean route.

The assessment in Appendix L presents a comparison of what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer sites (see Sections L.3.2.7 and L.4.2.2) The southern most of the three locations considered for the Apex/Dry Lake intermodal transfer site appears to be, at least in part, within a 100-year flood zone of a normally dry drainage channel (see Section L.3.2.7).

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Upgrades to the Apex/Dry Lake route would not require any water wells. The road upgrades would require an estimate total of about 9,200 cubic meters (8 acre-feet) of water (DIRS 104917-LeFever 1998, all). Options for obtaining this water would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (about 500 truckloads) to construction sites, or use a combination of these two actions.

Operations. Section 6.3.3.1 discusses impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul routes.

6.3.3.2.5.4 Apex/Dry Lake Route Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer stations and routes. This section discusses the construction- and operations-related impacts that would be unique to the Apex/Dry Lake intermodal station and route.

Highway Construction and Upgrades. DOE has identified three areas for the construction of an Apex/Dry Lake intermodal transfer station. The predominant land cover type at these sites (creosote-bursage) and it is extensively distributed in the region (DIRS 104593-CRWMS M&O 1999, pp. 3-36 and C1 to C5). Considerable industrial development has occurred near the potential sites. The three sites are in the range of the threatened desert tortoise, although none is in an area considered to be critical habitat for the tortoise (50 CFR 17.95). The construction site would disturb approximately 0.2 square kilometer (50 acres) of desert tortoise habitat. The likelihood of death or injury to tortoises due to construction activities would be small if DOE conducted surveys for tortoises in areas to be disturbed and moved tortoises in the immediate area out of harm's way. Geyer's milk vetch (BLM sensitive) occurs on the southern edge of one of the proposed locations of the Apex/Dry Lake intermodal transfer station (DIRS 104593-CRWMS M&O 1999, p. 3-37). If this location for an intermodal transfer station was selected, DOE would conduct pre-activity surveys for this plant's species and would avoid occupied habitat if possible. There are no designated game habitats at the proposed locations for the intermodal transfer station, or any springs or other areas that could be classified as wetlands (DIRS 104593-CRWMS M&O 1999, p. 3-37).

The predominant land cover types along the Apex/Dry Lake heavy-haul truck route are creosote-bursage and Mojave mixed scrub, which are common throughout this region (DIRS 104593-CRWMS M&O 1999, pp. 3-34, and C1 to C5). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

The only resident threatened or endangered species that occurs along the Apex/Dry Lake route is the desert tortoise. Desert tortoise habitat occurs along the entire length of the route (DIRS 103160-Bury and Germano 1994, pp. 57 to 72; 50 CFR 17.95). Construction activities could kill or injure desert tortoises; however, losses would be few because construction would occur only on the right-of-way and desert tortoises are uncommon adjacent to heavily traveled roads (DIRS 103160-Bury and Germano 1994, Appendix D, p. D12). Three other special status species occur along this route (DIRS 104593-CRWMS M&O 1999, p. 3-35) but because construction activities would be limited to the road and adjacent areas, occupied habitat would not be destroyed and these species should not be affected.

This route would not cross any areas designated as game habitat or springs or possible wetlands (DIRS 104593-CRWMS M&O 1999, p. 3-35). The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and obtain individual, regional, or nationwide permits, as appropriate. Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impact to soils would be small.

6.3.3.2.5.5 Apex/Dry Lake Route Cultural Resources

Highway Construction and Upgrades. A total of 51 archaeological and historic sites have been recorded along the highway rights-of-way that comprise the Apex/Dry Lake intermodal transfer station site and heavy-haul truck route (DIRS 155826-Nickens and Hartwell 2001, all). None of these previously recorded cultural sites are in locations proposed for upgrades.

There are no recorded cultural resources that would be affected by the construction of an Apex/Dry Lake intermodal transfer station. However, an original segment of the historic Arrowhead Trail Highway passes through the northern intermodal transfer station site location, and includes the archaeological remains of a motel and gas station. Based on previous archaeological studies in the larger area, there is a probability that there are one or more construction camps from the initial railroad construction era in the proposed intermodal transfer station locations as well.

The route follows a portion of U.S. 95 that passes though approximately 1.6 kilometers (1 mile) of the Las Vegas Paiute Reservation. The intermodal transfer station would be along I-15, about 3 kilometers (2 miles) south of the Moapa Paiute Reservation. Construction of the intermodal transfer station and use of U.S. 95 for this route would not have adverse impacts on Native American sites or values.

Operations. Use of an Apex/Dry Lake intermodal transfer station and heavy-haul truck route would not involve impacts (such as disturbing the sites or crushing artifacts) to known cultural resource sites.

6.3.3.2.5.6 Apex/Dry Lake Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Apex/Dry Lake route. The impacts of the Apex/Dry Lake intermodal transfer station would be the same as those discussed in Section 6.3.3.1.

Table 6-115. Impacts to workers from industrial hazards from upgrading highways along the Apex/Dry Lake route.

Group and trauma category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	22	120
Lost workday cases	11	66
Fatalities	0.03	0.33
Noninvolved workers[d]		
Total recordable cases	1.3	6.8
Lost workday cases	0.5	2.5
Fatalities	0.001	0.007
Totals[e]		
Total recordable cases	23	130
Lost workday cases	11	68
Fatalities	0.032	0.34

a. Impacts are totals over about 28 months.
b. Includes periodic maintenance and resurfacing. Impacts are totals over about 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Highway Construction and Upgrades. Industrial safety impacts on workers from upgrading highways for the Apex/Dry Lake route would be small (see Table 6-115). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatalities for workers, and traffic fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-116 lists the estimated fatalities from construction and commuter vehicle traffic.

Operations. Incident-free radiological impacts listed in Table 6-117 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the route. These impacts would include transportation along the route as well as transportation along railways in Nevada leading to an Apex/Dry Lake intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-116. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Apex/Dry Lake route for heavy-haul trucks.[a]

Activity	Kilometers[b]	Traffic fatalities	Vehicle emissions fatalities
Construction[c]			
Material delivery vehicles	15,000,000	0.3	0.03
Commuting workers	20,000,000	0.2	0.03
Subtotals	*35,000,000*	*0.5*	*0.06*
Operations[d]			
Commuting workers	120,000,000	1.2	0.16
Totals	***160,000,000***	***1.7***	***0.22***

a. Includes impacts of construction and operation of an intermodal transfer station.
b. To convert kilometers to miles, multiply by 0.62137.
c. Impacts are totals over about 28 months.
d. Impacts are totals over 24 years.

Table 6-117. Health impacts[a] from incident-free Nevada transportation for the Apex/Dry Lake heavy-haul truck implementing alternative.

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	38	1,100	1,100
Estimated latent cancer fatalities	0.02	0.44	0.46
Public			
Collective dose (person-rem)	7	150	160
Estimated latent cancer fatalities	0.003	0.08	0.08
Estimated vehicle emission-related fatalities	0.002	0.064	0.066

a. Impacts are totals for 24 years.
b. Includes impacts to workers at an intermodal transfer station.
c. Totals might differ from sums of values due to rounding.

6.3.3.2.5.7 Apex/Dry Lake Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways along an Apex/Dry Lake route, advancing the construction schedule for a section of the planned Las Vegas Beltway to accommodate heavy-haul trucks, and building an intermodal transfer station. The section also describes socioeconomic impacts from the operation of an intermodal transfer station in Clark County and the periodic resurfacing of highways.

This analysis of economic measures assumed that Clark County would secure a loan to advance the construction schedule of the section of the Las Vegas Beltway that would be part of this heavy-haul truck route. The analysis based the estimates for a range of impacts on two sources of information from Clark County about the cost of building a section of the Beltway. Modifications to the Beltway would cost between $40 million (DIRS 103710-Clark County 1997, p. 2-7) and $425 million in 1998 dollars (DIRS 155112-Berger Group 2000, p. 29) (about $43.6 million to $463 million in 2001 dollars). DOE believes the actual cost would be between these values. A loan to Clark County for $43.6 million or $463 million, at an annual rate of 3 percent, with the repayment of the loan starting in 2010 and lasting for 30 years, is a part of the modeling to determine the impacts to employment, population, real disposable income, and expenditures by State and local governments. (A *real* percentage rate is the premium paid in addition to the rate of inflation; a real rate plus the rate of inflation equals the nominal or quoted rate.) Clark County would repay the loan from tax revenues. DOE assumes most repayment funds would be from sources the county has already identified for completion of the Beltway.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading highways for an Apex/Dry Lake route, advancing the schedule for construction of a portion of the Las Vegas Beltway, and building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. The highway upgrades, excluding the Beltway, would cost $20.8 million, require about 28 months to complete, and occur during the 48-month construction period for the Beltway. Building an intermodal transfer station would cost about $25.0 million and take 18 months to complete. If this route was selected, the construction schedule of the planned Las Vegas Beltway would be advanced. (Dollar values reported in this section are 2001 dollars unless otherwise stated.)

This discussion expresses values for socioeconomic measures (employment, population, real disposable income, Gross Regional Product, and State and local government expenditures) and for potential impacts that would change in those measures as a range of values. The first value refers to the outcome if the Beltway cost is $43.6 million; the second refers to the outcome if the Beltway cost is $463 million. DOE anticipates that the actual change would be between the two values.

Employment

Employment in the region of influence of construction workers involved with upgrading the highways (including the Beltway) or with building an intermodal transfer station (direct workers) and other workers who would be employed as a result of the economic activity generated by the project (indirect workers) would peak in 2008. Employment increases would be between 490 and 1,882 jobs. The increase in employment in Clark County would be between 482 and 1,848 workers, Nye County would gain between 6 and 27 workers, and Lincoln County would gain between 1 and 5 workers. The increases in Clark, Nye, and Lincoln Counties would be less than 1 percent of the employment baseline for each county.

Population

The increase in employment would also bring population increases in the region of influence that would peak in 2009. During that year, the incremental increase in population would be between 356 and 1,857 individuals. Clark County would experience about 97 percent of this impact. The increase in population for Clark County would be between 347 and 1,812, for Lincoln County between 0 and 5, and for Nye County between 7 and 39. The impact from an increase in population as a result of increased employment opportunities would be less than 1 percent of each county's population baseline. Because the increases in population in each county would be small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Economic measures would rise during the construction of an intermodal transfer station and the upgrading of highways and Las Vegas Beltway. The increase in real disposable income of people in the three-county region of influence would peak in 2008 at between $15.7 million and $62.0 million. The region-wide increase in Gross Regional Product would peak in 2008 at between $28.9 million and $99.8 million. Increased State and local government expenditures would peak in 2009 at between $1.2 million and $6.1 million. More than 97 percent of this economic activity would be concentrated in Clark County. The Gross Regional Product, real disposable income, and expenditures by State and local governments would rise by less than 1 percent in Clark, Nye, and Lincoln Counties. (All dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Apex/Dry Lake heavy-haul truck route workers and indirect (support) workers would decrease by 419 to 2,026 when construction of the intermodal transfer station and highway upgrades (including the Beltway portion) ended in 2009. Clark County would lose between 412 and 1,993 of these jobs, Nye County would lose between 6 and 28 of these jobs, and Lincoln County would lose between 1 and 5 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Apex/Dry Lake route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and continue until 2033. A direct workforce of about 26 would be required for the intermodal transfer station. Direct employment for heavy-haul truck operations over an Apex/Dry Lake route, including Clark County-based shipment escorts, would be about 66 workers. DOE assumed that operations workers would reside in Clark County.

To analyze the socioeconomic impacts of operations for an Apex/Dry Lake route, DOE considered three activities: operation of the intermodal transfer station, operation of the heavy-haul trucks, and maintenance of the highways and the Las Vegas Beltway.

Employment and Population

Employment in the region of influence associated with the operations of an intermodal transfer station and heavy-haul trucks would average about 99 workers, all of whom would work in Clark County. The impact on population from these two activities would be an average of 129 workers of whom 127 would live in Clark County. These impacts to employment and population would be less than 1 percent of the baseline in Clark County. During periodic road resurfacing, employment (direct and indirect) in the region would increase by about 107 workers for 2 years. DOE assumed that all of these workers would come from Clark County-based firms. Overall, employment increases from periodic highway resurfacing projects (every 8 years starting in 2016) would be less than 1 percent of the baseline for Clark County. Given the short duration of each resurfacing project, there would be no perceptible change in the region's population.

Net changes to employment and population from all three portions of the Apex/Dry Lake heavy-haul truck route during the 24-year operations phase can be summarized. There would be an incremental increase of 90 positions in the region of influence, with 89 of the additional positions in Clark County if the cost of the beltway was approximately $43.6 million. The region of influence would experience a growth in population of an additional 137 residents, 132 of them in Clark County. This impact would be less than 1 percent of the baseline. If the cost of the beltway reaches $463 million, the region of influence (while continuing to grow to an average of 1.1 million jobs), would have 242 fewer employment positions, with 241 of these in Clark County. Population, which is driven by employment, would be affected. The region of influence would have 511 fewer residents and Clark County would have 519 fewer residents. The impacts at the upper range of the cost estimates would be less than 1 percent of the baselines. Because the impacts would be so small, impacts to housing or schools would be unlikely.

Economic Measures

Impacts from changes to the economic measures of real disposable income, Gross Regional Product, and expenditures by State and local governments from operating an intermodal transfer station at Apex/Dry Lake, operating heavy-haul trucks, and maintaining the highways would fluctuate throughout the operations period and would depend partially on changes in population and employment. If the beltway cost was at the lower end of the cost estimate, real disposable income and Gross Regional Product in the region of influence would rise during the operations period. The increase in real disposable income would average $3.6 million and in Gross Regional Product would average $8.2 million. Expenditures by governments would increase over the 24-year period by an average of $479,000. Virtually all of the activity would be concentrated in Clark County and would be less than 1 percent of the various baselines. If the final cost of the beltway was $463 million, the impacts would be more visible but still less than 1 percent of the applicable baselines. Real disposable income would decline from $4.0 million above the baseline in 2010 to $35.6 million below the baseline by 2033, an average of slowing growth in this area of $29.2 million. The region of influence would have an average real disposable income of $55,797,000 during this period. Gross Regional Product would remain below the baseline, averaging $11.2 million annually. Expenditures by government would decline from $5.4 million above the baseline in 2010 to $4.5 million below the baseline in 2033. The average would be a slowing of spending by $1.9 million. As population growth slows, there would be a slowing in the rate of tax revenues collected and a slowing in the rate of population growth that would require a given level of services.

6.3.3.2.5.8 Apex/Dry Lake Route Noise and Vibration

Section 6.3.3.1 discusses noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on noise impacts that would be unique to the Apex/Dry Lake heavy-haul truck implementing alternative.

Highway Construction and Upgrades. There is one residence near the Dry Lake site of the three tracts of land identified for an intermodal transfer station. Construction noise would occur during daylight hours and would be a temporary source of elevated noise in the area. Nighttime noise impacts would be unlikely because construction activities would not occur at night.

For the Apex/Dry Lake route, northern Las Vegas, the Town of Indian Springs, and the rural community of Cactus Springs are within the 2,000-meter (6,600-foot) region of influence for construction noise. Construction activities would occur at the I-15 interchange at Apex and along sections of U.S. 95. The route, which passes north of Las Vegas, is not heavily populated and the potential for noise-related construction impacts would be low.

Operations. An Apex/Dry Lake intermodal transfer station would be isolated, with one residence (DIRS 155825-Poston 2001, all) in the vicinity, adjacent to an existing rail line. The potential for noise impacts is unlikely unless operations were close to this residence.

The Apex/Dry Lake route would be confined to established highways with wide shoulders. Background traffic noise levels would be greatest along the planned northern Beltway, reducing the potential for heavy-haul truck noise to affect public receptors adversely during daylight hours. The incremental noise increase due to the infrequent heavy-haul truck shipments would not alter the existing noise environment. Estimated noise levels (1-hour average sound levels) at Indian Springs and Cactus Springs would increase by about 0.4 dBA [at 15 meters (44 feet) from the road] due to heavy-haul truck traffic. A potential receptor is the public school in Indian Springs, which also serves students from Cactus Springs. The Indian Springs school is about 300 meters (980 feet) south of U.S. 95. The incremental contribution of heavy-haul trucks at this distance from the highway would not be perceptible. No historic buildings would be affected by ground vibration. No sensitive ruins of cultural significance have been identified along this route.

The Apex/Dry Lake intermodal transfer station is about 3 kilometers (2 miles) from the Moapa Reservation. Assuming that the greatest source of noise would be locomotives, estimated noise levels at 520 meters (1,700 feet) would be 45 dBA. Noise generated at the intermodal transfer station would not be perceptible 910 meters (3,000 feet) away at the border of the Moapa Reservation. The Apex/Dry Lake heavy-haul truck route on U.S. 95 also passes through about 1.6 kilometers (1 mile) of the Las Vegas Paiute Reservation. Because of the relatively large traffic volume on U.S. 95, the increase in traffic noise due to heavy-haul trucks in this area would not be perceptible (DIRS 155825-Poston 2001, all).

6.3.3.2.5.9 Apex/Dry Lake Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses the utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy and materials impacts that would be unique to the Apex/Dry Lake heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Apex/Dry Lake intermodal transfer station would have the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

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Table 6-118 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Apex/Dry Lake route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-118. Utilities, energy, and materials required for upgrades along the Apex/Dry Lake route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Apex/Dry Lake	182	1.6	29	0.23	0.1	2.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.4 ENVIRONMENTAL JUSTICE IMPACTS IN NEVADA

The analysis considered existing highways and railroads that DOE would use in Nevada—I-15, the proposed Las Vegas Beltway; U.S. 95; five possible highway routes for heavy-haul trucks; the Union Pacific Railroad's mainlines in northern and southern Nevada; and five corridors with variations for a possible branch rail line in the State. If DOE constructed and operated the repository, it would use combinations of these routes for shipments of spent nuclear fuel and high-level radioactive waste. DOE would use alternative preferred routes designated by the State of Nevada for highway shipments to the repository.

In general, the consequences of using a transportation route would occur close to the route. Thus, for transportation on a highway or railroad to affect a census block group for which environmental justice concerns could exist, the route would have to cross or be adjacent to the block group. Chapter 3, Section 3.1.13 discusses and depicts the minority and low-income populations in Nevada.

Portions of some routes would cross or be adjacent to Native American tribal lands. Existing or proposed highway routes avoid census block groups with high fractions of minority, low-income, or Native American populations with the exceptions of:

- Sections of I-15 that pass through the center of the Moapa Reservation northeast of Las Vegas, Nevada
- A 1.6-kilometer (1-mile) section of U.S. 95 across the southwest corner of the Las Vegas Paiute Indian Reservation that could be used by legal-weight trucks as well as either the Caliente/Las Vegas or Apex/Dry Lake heavy-haul truck route
- The Caliente/Las Vegas and Apex/Dry Lake routes for heavy-haul trucks, which would pass near the Moapa Reservation
- Sparsely populated areas of census block groups in the northern parts of Clark County

Existing or proposed rail routes could cross census block groups with high populations of minority, low-income, or populations of Native Americans only at the following points:

- The Union Pacific Railroad's mainline tracks pass through the center of the Moapa Reservation and through the center of Las Vegas, Nevada, crossing census block groups with high fractions of minority and low-income populations.
- The Bonnie Claire Alternate of the Caliente and Carlin Corridors would pass through 4.5 kilometers (2.8 miles) covering 1.8 square kilometers (450 acres) of the Scottys Junction portion of the newly designated Timbisha Shoshone Trust Lands parcel planned for residential use and tourist-related business.

Also, a branch rail line in the Valley Modified Corridor would pass near the Las Vegas Paiute Reservation. None of the potential intermodal transfer station sites that DOE could use would be near a census block group with high minority or low-income populations, but an intermodal transfer station in the Apex/Dry Lake area could be as close as about 3 kilometers (2 miles) to the Moapa Reservation.

Impacts to resource areas other than environmental justice along Nevada highways and railroads from the transportation of spent nuclear fuel and high-level radioactive waste would be small. The number of shipments in the mostly legal-weight truck and mostly rail scenarios would be small in comparison to the number of all other commercial shipments in southern Nevada. For comparison, under the mostly legal-weight truck scenario as many as five trucks carrying spent nuclear fuel would pass through the Moapa Indian Reservation on I-15 each day compared to daily traffic of more than 3,000 commercial trucks that use this section of highway (DIRS 156930-NDOT 2001, p. 6; DIRS 104727-Cerocke 1998, all). Under the mostly rail scenario as many as 11 railcars per week carrying spent nuclear fuel could travel into southern Nevada compared to about 1,000 railcars each day for other commodities. Thus, impacts from truck and rail traffic and emissions would be small for these shipments. The potential for accidents that could result in injuries or fatalities involving the shipments would also be small in comparison to the overall risk of accidents that would occur from other commercial traffic.

As much as 10 percent of travel in southern Nevada by legal-weight trucks or railcars carrying spent nuclear fuel would be through populations of Native Americans and census block groups with high fractions of minorities or low-income populations, depending on the selected route and transportation mode. Public health and safety impacts to all populations in Nevada would be small (about 1 fatality from cancer and other causes for incident-free transportation and 0.00006 latent cancer fatality for accidents over 24 years).

The public health and safety impacts to minority and low-income populations along the routes of travel would also be small. Because the probability would be small at any single location, the risk of an accident at a specific location would also be small. Thus, impacts to minority or low-income populations or to populations of Native Americans in small communities along the routes would also be small and, therefore, unlikely to be disproportionately high and adverse.

Unique practices and activities could create opportunities for increased impacts from transportation of spent nuclear fuel and high-level radioactive waste associated with the Proposed Action. One such practice could be the use of subsistence diets (that is, consumption of homegrown or naturally available plant and animal food). Because no radioactive materials would be released to the environment during incident-free transportation, the implementation of new or existing transportation routes in Nevada would not affect food sources likely to be involved in subsistence diets. If an accident resulted in the release of radioactive materials, food sources, both agricultural and subsistence, could be affected and mitigative actions would have to be taken to prevent contamination or consumption of contaminated food.

The American Indian Writers Subgroup identified noise from transportation as a concern because of its effects on ceremonies and the solitude necessary for healing and praying (DIRS 102043-AIWS 1998, p. 2-19). DOE is not aware of traditional cultural properties or other areas along the candidate rail corridors or routes for heavy-haul trucks, including variations, where noise from trains, construction of a branch rail line or intermodal transfer station, or conduct of heavy-haul or other trucking operations could interfere with conditions necessary for meditation by, or religious ceremonies of, Native Americans, with the exception of the Caliente Intermodal Transfer Station, as noted below. Similarly, no known ruins or other culturally sensitive structures have been identified that could be affected by ground vibration.

The analysis of transportation-related construction or upgrades identified potentially adverse impacts pertaining to certain routes or transportation modes. DOE could lessen some of these impacts through mitigation, as discussed in Chapter 9. Adverse impacts could include the following:

- The Valley Modified Corridor and some of its variations would involve construction in the Las Vegas Valley air basin, which is in serious nonattainment for particulate matter (PM_{10}) and carbon monoxide (DIRS 155557-Clark County 2001, Tables 3-8 and 5-3). Emission rates would exceed the General Conformity threshold (established by Environmental Protection Agency regulations that implement the Clean Air Act) for PM_{10} for a serious nonattainment area and would qualify the construction as a major source of emissions when evaluated under the Prevention of Significant Deterioration threshold. Comparison of this corridor with known locations of minority and low-income populations indicates that effects on such populations would not be disproportionately high and adverse in comparison with effects on the rest of the population. No unique practices or pathways have been identified that would increase impacts to minority or low-income populations. PM_{10} and carbon monoxide emissions are susceptible to mitigation.

- The northernmost site for a Sloan/Jean intermodal transfer station is in a PM_{10} nonattainment area. Emission rates would exceed the PM_{10} General Conformity threshold for a serious nonattainment area. Comparison of the Sloan/Jean route with known locations of minority and low-income populations indicates that effects on such populations would not be disproportionately high and adverse in comparison with effects on the rest of the population. No unique practices or pathways have been identified that would increase impacts to minority or low-income populations. PM_{10} and carbon monoxide emissions are susceptible to mitigation.

- Most of the road upgrades for a Sloan/Jean heavy-haul truck route would occur in areas that are in attainment for criteria pollutants. However, portions of the upgrades would occur in the Las Vegas Valley air basin, which is in nonattainment for carbon monoxide and PM_{10}. Comparison of the route with known locations of minority and low-income populations indicates that effects from road upgrades on such populations would not be disproportionately high and adverse in comparison with effects on the rest of the population. No unique practices or pathways have been identified that would increase impacts to minority or low-income populations. PM_{10} and carbon monoxide emissions are susceptible to mitigation.

- Construction and operation of a Caliente intermodal transfer station could cause aesthetic impacts to users of Kershaw-Ryan State Park. Impacts could result from construction activities and from noise, traffic, and lighting during operations. Impacts would be similar for all park users and, therefore, would not be disproportionately high and adverse for members of minority or low-income populations. Some of these impacts would be susceptible to mitigation.

- Biology and soils impacts from construction and from corridor and route occupancy and use would include long-term vegetation disturbance in corridors or at an intermodal transfer station and stopover sites. Short-term or individual impacts to threatened and endangered and special-status species could occur. The Valley Modified Corridor crosses two wilderness study areas and a national wildlife refuge. DOE has found no location-related or unique practices and pathways information to indicate that effects on minority or low-income populations would be disproportionately high and adverse in comparison with effects on the rest of the population.

- The construction and operation of a branch rail line in the Caliente or Carlin Corridor along the Bonnie Claire Alternate would cross the Scottys Junction parcel of the Timbisha Shoshone Trust Lands. Sections 6.3.2.2.1 and 6.3.2.2.2 discuss land-use and noise consequences for potential residents. Information available to DOE indicates that the Timbisha Shoshone have not developed residential areas on the parcel. Because residential development of the parcel has not occurred, there is no population present, no way to measure the likelihood of disproportionately high and adverse impacts on a possible minority or low-income population, and no present data indicating a potential for environmental justice concerns from the Bonnie Claire Alternate.

- The construction and operation of a branch rail line in any of the candidate rail corridors could present the potential for direct and indirect impacts to archaeological and historic resources related to Native American culture. Additional archaeological surveys and ethnographic studies are needed for the placement of an alignment within any of the rail corridors, including variations, to determine specific potential impacts and mitigation needs. Records searches indicate that only a small percentage of potentially affected lands in designated rights-of-way have been inspected.

- The operation of a heavy-haul truck route along any of the candidate routes could present the potential for direct and indirect impacts to archaeological and historic resources related to Native American culture. The determination of the potential for impacts to Native American cultural values from the upgrading and use of Nevada highways for heavy-haul truck shipments would require more study. The American Indian Writers Subgroup has commented that ethnographic field studies would be necessary to determine specific potential impacts to Native American cultural properties and values (DIRS 102043-AIWS 1998, p. 4-6) for candidate rail corridors and the use of existing highways as routes for heavy-haul trucks to Yucca Mountain.

- Construction of a Carlin branch rail line could affect two known historic-period Native American cemeteries, one in Crescent Valley and the other in Grass Valley (DIRS 155826-Nickens and Hartwell 2001, p. 27).

- Several rail corridors and routes for heavy-haul trucks pass through or are proximate to significant places for Native Americans. For example, in the Pahranagat National Wildlife Refuge, the Black Canyon area, the Storied Rocks site farther south, and the Maynard Lake vicinity have been identified. The entire Pahranagat Valley is an important cultural landscape (DIRS 155826 Nickens and Hartwell 2001, Appendix A). The Coyote Springs area and the Arrow Canyon Range valley south of the Pahranagat Valley are places of cultural importance. The operation of a Caliente intermodal transfer station could have a lasting impact on the cultural integrity of the location, which Native Americans have identified as an important place. The overall significance of such places and the potential for impacts from the transportation of spent nuclear fuel and high-level radioactive waste cannot be fully understood until a rail alignment or heavy-haul truck route is identified and ethnographic field studies and consultation have been completed.

In the viewpoint of Native Americans, the construction and operation of a branch rail line would constitute an intrusion on the holy lands of the Southern Paiute and Western Shoshone. In addition, some corridors pass through or near several significant places (see Chapter 3, Section 3.2.2.1.5). The American Indian Writers Subgroup has commented that the overall significance of these places and potential impacts from operation of a rail line on them cannot be fully understood until DOE has identified the rail alignment and completed ethnographic field studies and consultations (DIRS 102043-AIWS 1998, p. 4-6). If DOE selected a rail corridor, it would initiate additional engineering and environmental studies (including cultural resource surveys), conduct consultations with Federal agencies, the State of Nevada, and tribal governments, and perform additional National Environmental Policy Act reviews as a basis for final alignment selection and construction. DOE would address the mitigation of potential impacts to archaeological and historic sites during the identification, evaluation, and treatment planning phases of the cultural resource surveys.

For existing highways and mainline railroads, the added traffic would be minimal and shipments of spent nuclear fuel and high-level radioactive waste would be unlikely to affect land use, air quality, hydrology, biological resources and soils, cultural resources, socioeconomics, noise and vibration, or aesthetics, except as noted above. The analyses discussed in the preceding sections also determined that impacts to these resource areas from construction and operation of a branch rail line in any of the five potential rail corridors or construction of an intermodal transfer station and upgrading of highways in Nevada would be low.

Because the analyses did not identify large impacts for railroad and highway transportation of spent nuclear fuel and high-level radioactive waste in Nevada that would constitute credible adverse impacts on populations, workers, or individuals, adverse effects would be unlikely for any specific segment of the population, including minorities, low-income groups, and Native American tribes, except as noted above. Chapter 4, Section 4.1.13.4, contains an environmental justice discussion of a Native American perspective on the Proposed Action.

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Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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7

Environmental Impacts of the No-Action Alternative

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7. ENVIRONMENTAL IMPACTS OF THE NO-ACTION ALTERNATIVE

This chapter describes the potential impacts associated with the No-Action Alternative described in Chapter 2. Under the No-Action Alternative and consistent with the Nuclear Waste Policy Act, as amended [NWPA, Section 113(c)(3)], the U.S. Department of Energy (DOE) would terminate activities at Yucca Mountain and undertake site reclamation to mitigate any significant adverse environmental impacts. Commercial utilities and DOE would continue to manage spent nuclear fuel and high-level radioactive waste at 77 sites in the United States.

DOE analyzed the No-Action Alternative to serve as a basis for comparing the magnitude of potential environmental impacts in the Proposed Action. Under the No-Action Alternative, and consistent with the NWPA, DOE would terminate activities at Yucca Mountain and undertake site reclamation to mitigate any significant adverse environmental impacts. In addition, DOE would prepare a report to Congress, with its recommendations for further action to ensure the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. Under any future course that would include continued storage at the generator sites, commercial utilities and DOE would have to continue managing spent nuclear fuel and high-level radioactive waste in a manner that protected public health and safety and the environment. However, the future course that Congress, DOE, and the commercial utilities would take if Yucca Mountain were not approved is uncertain.

DOE recognizes that a number of possibilities could be pursued, including continued storage of spent nuclear fuel and high-level radioactive waste at its present location, or at one or more centralized location(s); the study and selection of another location for a deep geologic repository (Chapter 1 identifies the process and alternative sites previously selected by DOE for technical study as potential geologic repository locations); the development of new technologies (for example, transmutation); or reconsideration of alternatives to geologic disposal (as discussed in Chapter 2, Section 2.3.1). The environmental considerations of these possibilities have been analyzed in other contexts in other documents to varying degrees. DOE also recognizes that under the No-Action Alternative, there would be an increased probability of shutdown of operating reactors before operating license expiration due to the lack of adequate spent nuclear fuel storage capacity, with an attendant loss of electric power generation for that area or region. While the Department recognizes that many environmental impacts could result from shutting down nuclear power reactors, a full evaluation of such impacts (such as generation of additional air pollution from replacement sources of electricity) would be highly speculative because the choice of a replacement power source (importation, solar, gas, coal, etc.) would be regionally dependent, and the affected utilities would make the ultimate decision. Because the determination of local and regional impacts resulting from the loss of electric generating capacity for shutdown reactors, including the potential for increased electricity prices, would be speculative, the EIS does not include a detailed discussion.

Table 7-1 lists representative studies related specifically to centralized or regionalized interim storage, including alternatives evaluated in DOE National Environmental Policy Act documents, and summarizes the relevant environmental considerations. Those studies contain more information on the potential environmental impacts of centralized or regional interim storage.

In light of these uncertainties, DOE decided to illustrate the possibilities by focusing the analysis of the No-Action Alternative on the potential impacts of two scenarios—long-term storage of spent nuclear fuel and high-level radioactive waste at the current sites with effective institutional control for at least 10,000 years (Scenario 1), and long-term storage with no effective institutional control after about 100 years (Scenario 2). Although the Department agrees that neither of these scenarios is likely, it selected them for analysis because they provide a basis for comparison to the impacts of the Proposed Action and because they reflect a range of the impacts that could occur.

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 1 of 5).

Title and scope of storage analysis	Environmental and other considerations
Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste (DIRS 104832-DOE 1980, all)	
Evaluates a proposal to provide interim storage of spent nuclear fuel from U.S. power reactors before final disposal. The proposal would include acceptance of a limited amount of foreign spent fuel if such actions would contribute to U.S. nonproliferation goals. Evaluates several generic interim storage facility alternatives, including centralized storage at a few large ISFS facilities.	Analyses include a description of a *generic interim storage site environment* based primarily on data for the midwestern United States, and potential environmental effects of such a facility for ISFS facilities. Impacts evaluated include: natural resources, radiological impacts, land use, water use, ecological resources, air quality, traffic, noise, socioeconomics, waste management, utilities, aesthetics, transportation (including both to ISFS facilities and from ISFS facilities to the disposition facility), and safeguards and security.
Recommendations on the Proposed Monitored Retrievable Storage Facility (DIRS 103173-Clinch River 1985, all)	
Evaluates DOE proposal to consider the Clinch River Breeder Reactor and ORR sites in Tennessee for an MRS facility. Performed by the Clinch River MRS Task Force, which included three study groups: environmental, socioeconomic, and transportation. Public meetings and site visits were conducted by the study groups. Separate reports by each study group are summarized in findings, concerns, anticipated impacts, and recommended mitigations.	The Environmental Study Group's final report presented concerns and recommended mitigations for MRS construction impacts, damage to ecosystem from construction, special nuclear risks of construction, highway construction impacts, radiation protection of workers and the public, airborne effluents, aqueous releases, hazards from cask rupture, earthquakes, flooding, long-term radionuclide containment, secondary waste stream, local control, offsite emergency response, past contamination of the ORR, environmental data from the ORR, and MRS becoming a permanent waste storage site. The Socioeconomic Study Group's final report identified concerns or potentially negative impacts of an MRS and possible mitigations for business recruitment and expansion, residential recruitment and retention, institutional trust, pre- and postoperational impacts and costs, tourism and aesthetics, site neighbors, and legislative issues. The Transportation Study Group's final report defined areas of potential major impacts (for example, independent inspections, upgrades of railroad tracks, routing and upgrades to preferred highway truck routes, escorts, emergency response plans and training, and requirements applicable to private carriers), and presented findings and recommendations on accident probabilities, barge transport, cask safety and contents, prenotification, and safeguards.

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 2 of 5).

Title and scope of storage analysis	Environmental and other considerations
Monitored Retrievable Storage Submission to Congress, Volume 2: Environmental Assessment for a Monitored Retrievable Storage Facility (DIRS 104731-DOE 1986, Volume 2, all)	
Evaluates a proposal for the construction of a facility for monitored retrievable storage. Evaluates two facility design concepts at each of three candidate sites in Tennessee (Clinch River Breeder Reactor, ORR, and TVA Hartsville Nuclear Power Plant).	Evaluates impacts common to all three sites and unique to each site, including radiological, air quality, water quality and use, ecological resources, land use, socioeconomics, resource requirements, aesthetics, and transportation. Also evaluates relative advantages and disadvantages of the six site design combinations.
MRS System Study Summary Report (DIRS 104838-DOE 1989, all)	
Evaluates the role of the MRS facility in the waste management system.	Provides additional support to the general conclusion that an MRS facility provides tangible benefits to a waste management system, as articulated in the DOE 1986 MRS proposal to Congress (DIRS 104731-DOE 1986, Volume 2, all). Examines various system configurations in a series of separate publications: • Scenario development and system logistics • Facility design/schedule/cost implications • Alternative MRS storage concepts • Location of high-level radioactive waste packaging • Waste package designs • Transportation impact analyses • Role of waste storage in operations of the waste management system • Licensing impacts of an MRS facility • System reliability
Nuclear Waste Management Systems Issues Related to Transportation Cask Design: At-Reactor Spent Fuel Storage, Monitored Retrievable Storage and Modal Mix (DIRS 104889-Hoskins 1990, all)	
Provides the State of Nevada evaluation of the DOE MRS proposal and the Tennessee studies and position in response.	Addresses the DOE MRS proposal, which evaluated the option of implementing an integral MRS facility as part of a waste management system and the option of “no-MRS facility” as part of the waste management system. The criteria for the evaluation included health and safety, economic, environmental, political (for example, acceptability, public confidence, local and state attitudes), social (for example, fears and anxieties), fairness (for example, equity, intergenerational, utilities/ratepayer, liability, geographic, interutility, and government-utility), repository scheduling, and flexibility (technical and institutional factors).

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 3 of 5).

Title and scope of storage analysis	Environmental and other considerations
Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (DIRS 101802-DOE 1995, all)	
Analyzes transportation and centralized interim storage of existing and projected inventories of DOE spent nuclear fuel (including naval spent nuclear fuel) at one site. Considers five interim storage sites (Hanford, INEEL, ORR, SRS, and the Nevada Test Site).	Focuses on key discriminator disciplines at each of the five sites, including socioeconomics, utilities (electricity), materials and waste management, occupational and public health and safety (radiation effects and accidents), transportation, and uncertainties and conservatism. Discusses cumulative impacts and impacts of no action. Does not provide detailed discussions of land use, cultural resources, aesthetic/scenic resources, geologic resources, air quality, water resources, ecological resources, noise, and utilities and energy because there would be small impacts for these areas that would be indistinguishable among the alternatives.
Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (DIRS 101812-DOE 1996, all)	
Evaluates a proposal to manage FRR spent nuclear fuel. Evaluates a management alternative for acceptance and management of FRR spent fuel in the United States that includes regionalized storage at SRS, INEEL, Hanford, ORR, and the Nevada Test Site. Basic implementation components of the proposal include policy duration, financing arrangements, amount of FRR spent fuel, location for taking title to FRR spent fuel, marine transport, ports of entry, ground transport, FRR spent fuel management sites, and storage technologies.	Analyzes impacts from policy considerations, marine transport, port activities, ground transport, and fuel management sites. More specifically, for fuel management sites, analyzes impacts for occupational and public health and safety, waste management, cumulative impacts, mitigation measures, and environmental justice. Covers impacts for land use, socioeconomics, cultural resources, aesthetics, scenic resources, geology, water resources, air quality, ecology, noise, utilities and energy, and waste management in general.
Final Waste Management Programmatic Environmental Impact Statement For Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DIRS 101816-DOE 1997, all)	
Evaluates programmatic alternatives for managing various DOE wastes including HLW. Regionalized and centralized storage are among the management options evaluated. Under the regionalized alternatives, canisters from West Valley would be transported either to SRS or to Hanford, and HLW canisters would continue to be stored at Hanford, SRS, and INEEL until acceptance at the geologic repository. Under the centralized storage alternative, canisters would be transported from West Valley, INEEL, and SRS to Hanford, where they would be stored until acceptance at a geologic repository.	Describes regionalized and centralized sites based on available site-specific data and existing and planned storage facilities for HLW canisters. Impacts evaluated include health risks (includes transportation), air quality, water resources, ecological resources, economics, population, environmental justice, land use, infrastructure, cultural resources, and costs.

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 4 of 5).

Title and scope of storage analysis	Environmental and other considerations
Environmental Report for the Private Fuel Storage Limited Liability Company's (PFS) Proposed Independent Spent Fuel Storage Installation (ISFSI) License Application (DIRS 103436-PFS 1997, all)	
Evaluates the impacts of a privately owned dry fuel storage facility proposed to be built in western Utah on the Skull Valley Goshute Indian Reservation. The facility would receive and store as much as 40,000 MTHM from several commercial nuclear reactor plants. In June of 2000, the NRC published a Draft EIS to support its licensing process for this facility.	Provides detailed descriptions and environmental impact analyses associated with construction and operation of the site and transportation corridors for geography, land use, and demography; ecological resources; climatology and meteorology (including air quality); hydrological resources; mineral resources; seismology; socioeconomics (including environmental justice analysis); noise and traffic; regional historic and cultural resources; scenic and natural resources; background radiological characteristics; and transportation (radiological and nonradiological impacts). Addresses installation siting and design alternatives based on several specific evaluation criteria (geography and demography; ecology; meteorology; hydrology; geology; regional historic/archaeological/architectural/scenic, cultural/natural features; noise; radiological characteristics).
Centralized Interim Storage Facility Topical Safety Analysis Report (DIRS 103375-DOE 1998, all)	
Analyzes an above-ground temporary storage facility for up to 40,000 MTHM of commercial reactor spent nuclear fuel. The non-site-specific analysis concludes that DOE could construct and operate the commercial interim storage facility in a manner that protects public health and safety.	Describes generic site characteristics and design criteria developed to bound, to the extent possible, site-specific values once a CISF is selected. Generic site characteristics include meteorology, surface hydrology, geology, and seismology. Principal design parameters evaluated for normal and accident conditions include type of fuel, storage systems, fuel characteristics, tornado (wind and missile load), straight wind, floods, precipitation, snow and ice, seismicity (ground motion and surface faulting), volcanic eruption (ash fall), explosions, aircraft impact, proximity to uranium fuel cycle operations, ambient temperature, solar load, confinement, radiological protection, nuclear criticality, decommissioning, materials handling, and retrieval capability.

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 5 of 5).

Title and scope of storage analysis	Environmental and other considerations
Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Shull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, (DIRS 152001-NRC 2000, all)	
Evaluates the impacts of a privately owned dry fuel storage facility proposed to be built in western Utah on the Skull Valley Goshute Indian Reservation. The facility would receive and store as much as 40,000 MTHM from several commercial nuclear reactor plants.	Provides detailed descriptions and environmental impact analyses associated with construction and operation of the site and transportation corridors for geography, land use, and demography; ecological resources; climatology and meteorology (including air quality); hydrological resources; mineral resources; seismology; socioeconomics (including environmental justice analysis); noise and traffic; regional historic and cultural resources; scenic and natural resources; background radiological characteristics; and transportation (radiological and nonradiological impacts). Addresses installation siting and design alternatives based on several specific evaluation criteria (geography and demography; ecology; meteorology; hydrology; geology; regional historic/archaeological/architectural/scenic, cultural/natural features; noise; radiological characteristics). Provides impact analyses for the No-Action Alternative where NRC would not approve the license application to construct and operate the proposed storage facility and utilities would continue to store spent nuclear fuel at their reactor sites until it is shipped to a permanent geological repository.

a. Abbreviations: ISFS = independent spent fuel storage; ORR = Oak Ridge Reservation; MRS = monitored retrievable storage; TVA = Tennessee Valley Authority; INEEL = Idaho National Engineering and Environmental Laboratory; SRS = Savannah River Site; FRR = Foreign Research Reactor; HLW = high-level radioactive waste; MTHM = metric tons of heavy metal; NRC = U.S. Nuclear Regulatory Commission; CISF = centralized interim storage facility.

Chapter 2 describes the scenarios more fully. Appendix K contains detailed descriptions of the assumptions for each scenario. For consistency, the No-Action analysis considered the same spectrum of environmental impacts as the analysis of the Proposed Action. However, because of the DOE commitment to manage spent nuclear fuel and high-level radioactive waste safely and the uncertainties typical in predictions of the outcome of complex physical and biological phenomena over long periods, DOE decided to focus the No-Action analysis on the short- and long-term health and safety of workers and members of the public.

To ensure a consistent comparison with the Proposed Action for the cumulative effects analysis, the analysis included the impacts of the continued storage of spent nuclear fuel and high-level radioactive waste in excess of 70,000 metric tons of heavy metal (MTHM). This additional material, with the 70,000 MTHM under the Proposed Action (collectively called Module 1), includes 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, and 22,280 canisters of high-level radioactive waste.

In view of the almost unlimited possible future states of society and the importance of these states to future risk and dose, the National Research Council recommended the use of a particular set of assumptions about the biosphere (for example, how people get their food and water and from where) for compliance calculations such as those performed to evaluate long-term repository performance. Further, the National Research Council recommended the use of assumptions that reflect current technologies and living patterns (DIRS 100018-National Research Council 1995, p. 122). For consistency with the methods used to analyze environmental impacts from the proposed repository, the No-Action analysis selected current technologies and living patterns for the long-term impact evaluation, even though they might not represent an accurate prediction of future conditions.

DEFINITION OF METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

Under Scenario 1, 77 sites around the country would store spent nuclear fuel and high-level radioactive waste. For this scenario, the analysis assumed that institutional control for at least 10,000 years would ensure regular maintenance and continuous monitoring at the facilities, which would safeguard the health and safety of facility employees, surrounding communities, and the environment. All maintenance, including routine industrial maintenance and maintenance unique to a nuclear materials storage facility, would be performed under standard operating procedures or best management practices to ensure minimal releases of contaminants (industrial and nuclear) to the environment and minimal exposures to workers and the public. With institutional control, the facilities would be maintained to ensure that workers and the public received adequate protection in accordance with current Federal regulations such as 10 CFR Part 20 and Part 835 and DOE Order requirements (see Chapter 11, Tables 11-1, 11-3, and 11-4).

In addition, the Scenario 1 analysis assumed that storage facilities would undergo replacement every 100 years and would undergo major repairs halfway through the first 100-year cycle, because the storage facilities at any site would be built for a facility life of less than 100 years. (Federal regulations [10 CFR 72.42(a)] require license renewal every 20 years.) Figure 7-1 shows facility timelines for Scenarios 1 and 2.

DOE and commercial organizations intend to maintain control of the nuclear storage facilities as long as necessary to ensure public health and safety. However, to provide a basis for evaluating the upper limits of potential adverse human health impacts, Scenario 2 assumes no effective institutional control of the storage facilities after approximately the first 100 years. Therefore, after about 100 years and up to 10,000 years, the scenario assumes that spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial sites and 5 DOE sites would begin to deteriorate and that the radioactive materials in the spent nuclear fuel and high-level radioactive waste would eventually be released to the environment, contaminating the local soil, surface water, and groundwater. Appendix K contains the details of this long-term analysis.

For this environmental impact statement (EIS), DOE performed analyses to 10,000 years from the present. To parallel the repository analysis, the No-Action analysis considered both short- and long-term impacts. Short-term impacts would be those experienced during about the first 100 years, and long-term impacts would be those experienced during the remaining 9,900 years. Short-term impacts would be the

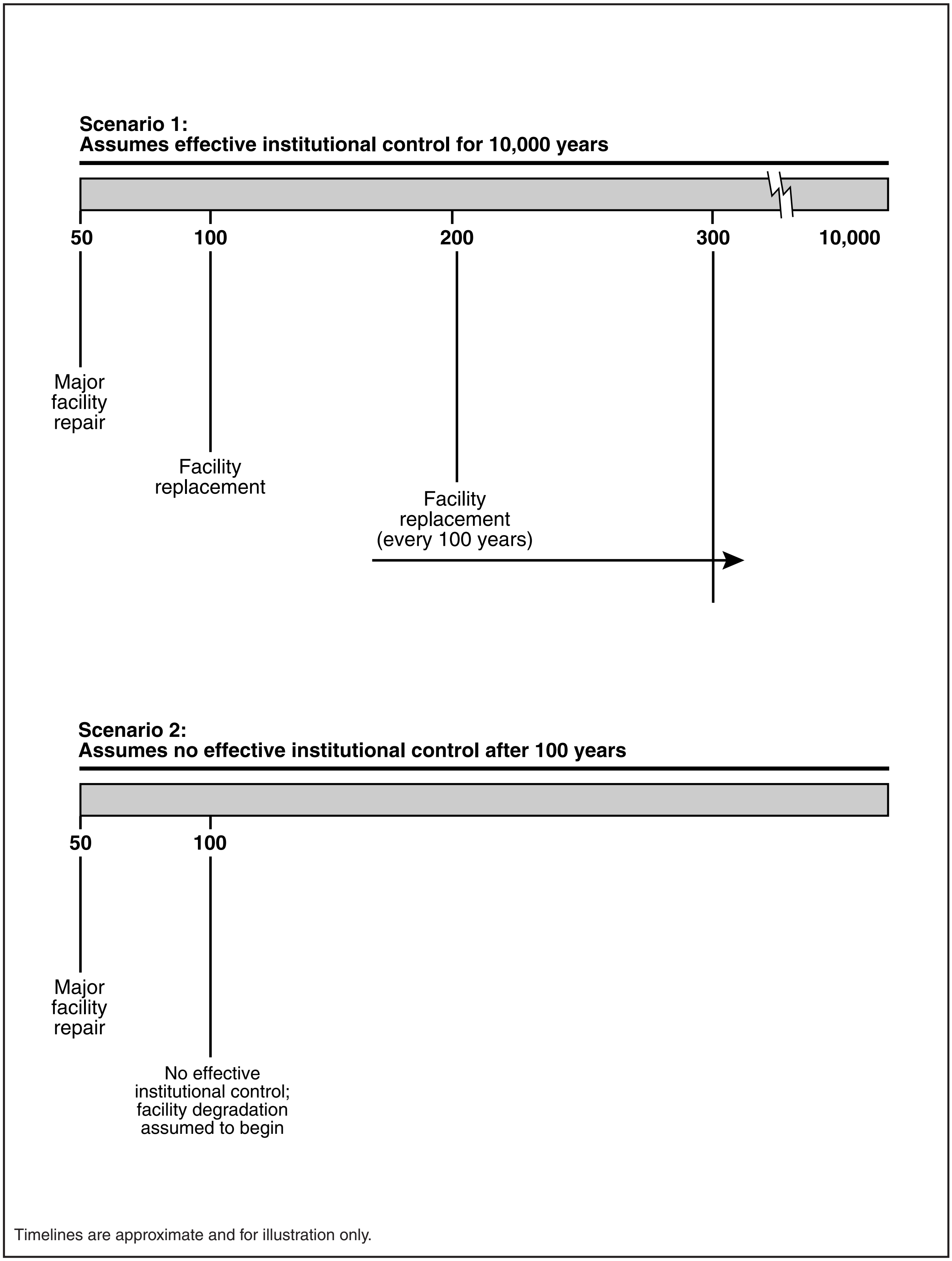

Figure 7-1. Facility timeline assumptions for No-Action Scenarios 1 and 2.

same under Scenarios 1 and 2 because both scenarios assume institutional control during this period. The short-term No-Action Alternative impacts include those resulting from the termination of activities at Yucca Mountain and decommissioning and reclamation of the site, so there would be no long-term impacts at the Yucca Mountain site. In addition, the short-term No-Action Alternative impacts at Yucca Mountain would be the same for both scenarios.

Impacts at the 77 sites after approximately 100 years (long-term) under Scenario 1 primarily would affect facility workers. Long-term impacts at the storage sites after approximately 100 years under Scenario 2 would affect only members of the public because the facility would close and there would be no workers (Scenario 2 assumes no effective institutional control after about 100 years).

To permit a comparison of both short- and long-term impacts from the construction, operation and monitoring, and eventual closure of a proposed repository at Yucca Mountain and from the No-Action Alternative, DOE took care to maintain as much consistency as possible in the methods used to analyze environmental impacts from the proposed repository and the No-Action Alternative. Important consistencies include the following:

- Identical spent nuclear fuel and high-level radioactive waste inventories:
  - Proposed Action: 63,000 metric tons of heavy metal (MTHM) of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, 8,315 canisters of high-level radioactive waste, and surplus weapons-usable plutonium (as mixed-oxide fuel or immobilized plutonium)
  - Module 1: Proposed Action materials plus an additional 42,414 MTHM of commercial spent nuclear fuel, 167 MTHM of DOE spent nuclear fuel, and 13,965 canisters of high-level radioactive waste resulting in a total of 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, and 22,280 canisters of high-level radioactive waste.

    This inventory includes surplus plutonium in the form of mixed-oxide fuel or immobilized plutonium (see Appendix A, Figure A-2).
- Identical evaluation periods of 100 years (short-term impacts) and of 100 to 10,000 years (long-term impacts)
- Consistent spent nuclear fuel and high-level radioactive waste corrosion and dissolution models
- Identical radiation dose and risk conversion factors
- Similar assumptions regarding the habits and behaviors of future population groups (that is, they would not be greatly different from those of populations today)

Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would improve long-term repository performance and reduce uncertainty. The result of the design evolution process was the development of the flexible design (DIRS 153849-DOE 2001, all), which was evaluated in the Supplement to the Draft EIS. This design focuses on controlling the temperature of the rock between waste emplacement drifts. As a result of these design changes, this Final EIS evaluates a range of repository operating modes (higher- to lower-temperature). The lower-temperature operating mode has the flexibility to remain open and under *active institutional control* for up to 300 years after emplacement. Although Chapter 4 of this EIS includes an evaluation of impacts for this period, DOE did not evaluate the 300-year institutional control case for the No-Action Alternative. The primary reason for not updating this part of the analysis was because if the institutional control period for the analysis of the No-Action Alternative were extended to 300 years, the short-term environmental impacts would have

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INSTITUTIONAL CONTROL

Institutional control implemented by commercial utilities and DOE provides monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements. Having attained this goal, institutional control ensures the maintenance of incurred doses as low as reasonably achievable, taking social and economic factors into account. Because the future course of action taken by the Nation and by commercial utilities would be uncertain if Yucca Mountain were not recommended as a repository site, the continued storage analysis evaluated two hypothetical scenarios with different assumptions about institutional control to bound potential environmental impacts.

The assumption for Scenario 1 is that DOE and commercial utilities would maintain institutional control of the storage facilities to ensure minimal releases of contaminants to the environment for at least 10,000 years.

Scenario 2 assumes no effective institutional control after approximately 100 years. DOE based the choice of 100 years on a review of generally applicable U.S. Environmental Protection Agency regulations for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191), U.S. Nuclear Regulatory Commission regulations for the disposal of low-level radioactive material (10 CFR Part 61), and the National Research Council report on standards for the proposed Yucca Mountain Repository (DIRS 100018-National Research Council 1995, p. 106), which generally discount the consideration of institutional control for longer periods in performance assessments for geologic repositories.

increased by as much as 3 times. DOE did not want to appear to overstate the impacts from the No-Action Alternative.

Since the publication of the Draft EIS, DOE modified the spent nuclear fuel cladding corrosion rates and failure mechanisms used in the performance analysis in Chapter 5 of the Final EIS. DOE did not update these models for the No-Action Alternative Scenario 2 analysis because the outcome would have been an increase in the long-term radiation doses and potential health impacts, however, the increase would be within the uncertainties discussed in Appendix K, Section K.4. In addition, the radionuclide inventories for commercial spent nuclear fuel were updated for the Final EIS (see Appendix A, Tables A-8 and A-9) to reflect the higher initial enrichments and burnup projected for commercial nuclear facilities. Although these revised inventories were used to estimate potential short-term repository impacts in the Final EIS (Chapter 4), DOE chose not to update the No-Action inventories because, again, the effect on the outcome would be about a 15-percent increase in health impacts in this chapter.

Affected populations for the No-Action Alternative were, in general, based on 1990 census estimates and not projected to 2035 as was done for the Proposed Action. However, if the population across the Nation had been projected to 2035, the collective impacts resulting from radiation exposure would have increased by less than a factor of 1.5, which is the average expected increase in national population from 1990 to 2035 (DIRS 152471-Bureau of the Census 2000, all).

7.1 Short-Term Impacts in the Yucca Mountain Vicinity

Chapter 3, Section 3.3, discusses the conditions at the sites that formed the basis for identifying potential impacts associated with the No-Action Alternative. The conditions include the relatively small incremental impacts resulting from continued characterization activities in the Yucca Mountain vicinity until 2002. Under the No-Action Alternative, DOE would terminate characterization activities at the site and would begin site decommissioning and reclamation. Decommissioning and reclamation would include dismantling and removing structures, shutting down some surface facilities, and rehabilitating land disturbed during characterization activities. DOE would salvage usable equipment and materials. Drill holes would be sealed, subsurface drifts and rooms would be left in place, and the portals would be gated. The piles of excavated rock from the tunnel would be landscaped. Areas disturbed by surface studies or used as laydown yards, borrow areas, or the like would be restored. Holding ponds would be backfilled or capped. DOE would not remove foundations or infrastructure such as access roads, parking lots, and sewage systems. The analysis assumed that reclamation activities would take about 1 year. Chapter 2, Section 2.2, describes the No-Action Alternative at Yucca Mountain.

The short-term impacts from reclamation of the Yucca Mountain site would occur regardless of the No-Action Alternative scenario and would be the same for both scenarios.

7.1.1 LAND USE AND OWNERSHIP

Land ownership and control could revert to the original controlling authority.

Under the No-Action Alternative, decommissioning and reclamation would begin as soon as practicable at the Yucca Mountain site, which DOE anticipates would happen in 2002. No new land would be required to support the decommissioning and reclamation activities. Because DOE stored topsoil and material from the mountain during site characterization, it would need no additional land to provide soil for reclaiming the material taken from the mountain or for backfilling holding ponds or the reclamation of other previously disturbed areas. Therefore, the No-Action Alternative would not require the disturbance of additional land at the site. The disturbed land would be restored to its approximate preconstruction condition about 100 years earlier than would occur under the Proposed Action.

7.1.2 AIR QUALITY

Transient effects on air quality would result from the exhausts of the heavy equipment that DOE would use during the decommissioning and reclamation activities that the Department expects to complete over a 1-year period. Recontouring and revegetation activities would generate dust containing particulate matter less than 10 micrometers in diameter (PM_{10}). Impacts on air quality would be about the same as those associated with the construction phase during the Proposed Action for the flexible design, as discussed in Chapter 4, Section 4.1.2, because less land would be disturbed by fewer vehicles during decommissioning and reclamation activities. Because the air quality impacts described in Section 4.1.2 represent a small fraction of the regulatory limit (that is, less than 10 percent of regulatory limits), the No-Action Alternative would not adversely affect air quality.

7.1.3 HYDROLOGY

7.1.3.1 Surface Water

The No-Action Alternative would not adversely affect surface water. During decommissioning and reclamation, adherence to such best management practices as stormwater pollution prevention plans would ensure that cleared areas and exposed earth would be seeded, graveled, or paved to control runoff and minimize soil erosion. To prevent contamination from heavy equipment, workers would monitor the equipment for leaks and would contain and clean up inadvertent spills of industrial fluids following established spill prevention and cleanup plans. DOE would dismantle and remove most surface structures, equipment, and building materials (DIRS 102188-YMP 1995, p. 2-8), including such items as fuel storage tanks and facilities where petroleum products or potentially hazardous materials like paints and solvents were stored before removal. Hazardous materials removed or generated during decommissioning would be taken from the site and reused, recycled, or disposed of in accordance with applicable regulations (DIRS 102188-YMP 1995, p. 2-8). After closure, contaminant sources would be gone so there could be no movement of contaminants to surface water. The analysis assumed that reclamation activities would be complete about 1 year after the decision to implement the No-Action Alternative, which DOE anticipates would occur in 2002.

As part of the reclamation activities, DOE would recontour the landscape to match its precharacterization conditions, ensuring natural drainage patterns. Because the North and South Portal ramps of the Exploratory Studies Facility slope upward to prevent ingress of surface water, they would not appreciably affect natural drainage patterns. Seeding and other erosion control measures would ensure normal infiltration rates. Under the No-Action Alternative, DOE anticipates that the restoration of natural drainage patterns would be complete about 100 years earlier than under the Proposed Action.

7.1.3.2 Groundwater

The No-Action Alternative would not adversely affect groundwater. DOE would remove all sources of contaminants (such as petroleum products and potentially hazardous materials like paints and solvents) from the site. The entrance ramps of the open portals of the Exploratory Studies Facility are sloped such that surface water would drain away from the openings. During reclamation activities (which would take about 1 year), the Exploratory Studies Facility portals would be closed.

7.1.4 BIOLOGICAL RESOURCES AND SOILS

Approximately 1.4 square kilometers (350 acres) of habitat has been disturbed; most of the disturbance is associated with the Exploratory Studies Facility, the storage area for the material removed from the tunnel, the topsoil storage area, borrow pits, boreholes, trenches, and roads. Site reclamation activities would include removal of structures and equipment, soil stabilization, and revegetation plantings at many of the disturbed sites (DIRS 102188-YMP 1995, all). Proper soil stabilization would prevent erosion. Once the area was reclaimed, stabilized, and planted with natural vegetation, and once activities at the site decreased, the precharacterization floral and faunal diversity would begin to reestablish itself. Some animal species could take advantage of abandoned tunnels for shelter; for example, the tunnels could provide attractive roosting and nesting sites for bats. Individuals of the threatened desert tortoise species could be adversely affected during the decommissioning and reclamation of the site. The No-Action Alternative would have no other adverse effects on biological resources or soils. In addition, the reclamation would result in the restoration of 1.4 square kilometers of habitat.

7.1.5 CULTURAL RESOURCES

The potential effects of other uses of the Yucca Mountain site on cultural resources are not known because no other uses have been identified; therefore, no assessment of the effects is possible. If the land were to revert to the previous controlling authorities, the stewardship of cultural resources would be consistent with applicable policies, regulations, and procedures.

Because no additional land would be required for decommissioning and reclamation activities, disturbances to cultural resources on undisturbed land in the area would be unlikely. Leaving access roads in place could have an adverse impact on cultural resources if the site boundaries are not secure. Preserving the integrity of important archaeological sites and resources important to Native Americans could be difficult if the public had increased access to the site.

7.1.6 SOCIOECONOMICS

Many of the repository workers would shift to decommissioning and reclamation tasks. An average annual workforce of about 1,800 would complete decommissioning and reclamation tasks at the repository site. After decommissioning and reclamation, the Nevada Test Site would assume the responsibility of preventing inadvertent entry to the North and South Portal areas. A small workforce would protect these areas after reclamation.

After the 1-year decommissioning and reclamation period, the decommissioning and reclamation workforce, along with about 1,400 project-related workers employed away from the repository site, would lose their jobs. The total direct employment reduction, therefore, would be about 3,200 at the completion of decommissioning and reclamation. For every direct job lost, about 0.46 indirect job would also be lost (DIRS 104508-CRWMS M&O 1999, all). *Indirect jobs* are those created as a result of direct employment; examples would include jobs that provide essential services, such as medical and police protection, to the individuals directly employed by the project. Therefore, the overall impact of the No-Action Alternative would be the loss of approximately 4,700 jobs in the region of influence.

As stated in Chapter 3, Section 3.1.7.1, approximately 79 percent of workers at the Yucca Mountain site reside in Clark County, 19 percent reside in Nye County, and less than 1 percent reside in Lincoln County or elsewhere. Thus, ending characterization activities would have the greatest potential impact in Clark County. If the region (Clark, Lincoln, and Nye Counties) continued to add about 2,800 new jobs every month, impacts would be offset by continued economic growth (Chapter 3, Section 3.1.7.2). Therefore, terminating site characterization activities would have a very minor impact on socioeconomic factors.

The cessation of repository activities would result in the loss of payments by the Federal Government in lieu of taxes. Nye County collects most of the monies associated with the repository project. The 1997 Nye County budget totaled approximately $83.8 million (county government and school district). During the same period, Nye County received approximately $5.4 million as payment in lieu of taxes (DIRS 105001-CRWMS M&O 1999, all).

7.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY FOR ROUTINE OPERATIONS

Chapter 2, Section 2.2.1, describes the actions DOE would take at Yucca Mountain under the No-Action Alternative. During the decommissioning and reclamation phase, these actions would expose workers and members of the public to the nonradioactive and radioactive contaminants discussed in Chapter 4, Section 4.1.3.1. In addition, these actions would place workers at risk for occupational (industrial safety) incidents such as illnesses, injuries, and fatalities. Appendix F, Section F.2.2.2, describes the statistics used to estimate health and safety impacts from industrial safety incidents. Because the activities that workers would perform under the No-Action Alternative would involve risks similar to those during the construction and closure phases of the Proposed Action, DOE used these statistics to estimate worker health impacts.

Worker exposures to nonradioactive contaminants of concern (diesel engine exhaust and mineral dusts potentially containing respirable erionite and crystalline silica) during decommissioning and reclamation activities would be limited by administrative and engineering means. Exposures would be maintained below occupational levels that could affect worker health adversely, as specified by the Occupational Safety and Health Administration and detailed in the project health and safety plan (DIRS 105032-CRWMS M&O 1999, all). Accordingly, worker exposures to nonradioactive contaminants would not contribute to adverse health impacts.

Tables 7-2 and 7-3 summarize the estimated total impacts from workplace industrial hazards and from radiological exposure, respectively, for reclamation activities. Table 7-4 summarizes impacts to members of the public.

Involved and noninvolved worker group losses under the No-Action Alternative would be about 94 total recordable cases of injury and illness, resulting in about 45 lost workday cases and no fatalities (Table 7-2).

Table 7-2. Estimated industrial safety impacts for surface and subsurface workers during decommissioning and reclamation activities at Yucca Mountain.[a]

Group	Total recordable cases	Lost workday cases	Fatalities
Involved workers	80	38	0
Noninvolved workers	13	7	0
Totals	***94***	***45***	***0***

a. Source: For impact statistics, Appendix F, Tables F-9 and F-10 (1 year of construction, higher-temperature operating mode, uncanistered packaging scenario).

Worker population radiation exposures during the year of decommissioning and reclamation activities would result from exposure to radioactive radon decay products that would emanate from the tunnel's rock matrix and from ambient radiation. Exposures to the subsurface workers could result in a collective dose of about 150 person-rem (Table 7-3). Doses to the maximally exposed involved subsurface worker and noninvolved worker could be as high as about 260 millirem and 70 millirem, respectively.

Table 7-3. Estimated radiation doses and health effects for surface and subsurface workers from decommissioning and reclamation activities at Yucca Mountain.[a,b]

Group	Maximally exposed individual (millirem)	LCF[c] risk to the maximally exposed individual	Collective worker dose[d] (person-rem)	LCF[e]
Involved workers	260	0.00010	140	0.055
Noninvolved workers	70	0.00027	7.4	0.0030
Totals	***NA***[f]	***NA***	***150***	***0.057***

a. Source: Appendix F, Table F-11; data adjusted for 1 year of construction activity.
b. The impacts listed would be the result of 1 year of decommissioning and reclamation activities; adapted from construction phase impacts. Worker doses would result from exposure to radon and other terrestrial radiation sources.
c. LCF = latent cancer fatality.
d. The calculation of doses and health effects assumes no worker rotation for exposure control purposes.
e. Expected number of cancer fatalities for populations. Based on a risk of 0.0004 latent cancer per rem for workers (DIRS 101857-NCRP 1993, p. 112).
f. NA = not applicable.

Public radiation exposures during decommissioning and reclamation would result from radon emissions from the subsurface facilities. These exposures could result in an annual dose to the hypothetical maximally exposed individual, about 18 kilometers (11 miles) south of the repository, of 0.43 millirem. The maximum collective dose to the projected population of 76,000 within 80 kilometers (50 miles) would be about 1.7 person-rem (Table 7-4).

Table 7-4. Estimated public radiation doses and health effects from decommissioning and reclamation activities at Yucca Mountain.[a]

Group	Maximally exposed individual (millirem per year)	Annual increase in risk for contracting an LCF[b]	Collective public dose[c] (person-rem)	LCF
Public	0.43	0.00000022	1.7	0.00085

a. The impacts listed would be the result of 1 year of decommissioning and reclamation activities (Table 4-2, higher-temperature operating mode, which was assumed to equate to 1 year of initial construction activities).
b. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101857-NCRP 1993, p. 112), and a life expectancy of 70 years for a member of the public.
c. The collective dose to 76,000 individuals living within 80 kilometers (50 miles) would be from radon emissions from the subsurface facilities.

The increased likelihood of the maximally exposed individual worker experiencing a latent cancer fatality would be very small.

7.1.8 ACCIDENTS

Under the No-Action Alternative, DOE would not ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain, and there would be only limited quantities of nonradioactive hazardous or toxic substances. Therefore, accident impacts would be limited to those from traffic and industrial hazards.

Table 7-2 lists impacts from industrial accident scenarios and Section 7.1.14 discusses impacts from traffic accident scenarios.

7.1.9 NOISE

Noise levels during decommissioning and reclamation activities would be no greater than those of site characterization activities. After the decommissioning and reclamation activities were complete, ambient noise would return to levels consistent with a desert environment where natural phenomena account for most background noise (see Chapter 3, Section 3.1.9.1). The No-Action Alternative would not adversely affect the noise levels of the Yucca Mountain region.

7.1.10 AESTHETICS

Site decommissioning and reclamation activities would improve the scenic value of the site. Borrow pits and holding ponds would be filled or graded, stabilized, and revegetated. Most structures would be removed down to their foundations. The North and South Portals would be gated. The surface area of these disturbed areas would represent a small fraction of the total surface area of the repository site and, therefore, would be unlikely to cause adverse impacts to the overall scenic value of the area. Under the No-Action Alternative, the site would be returned to a state as close as possible to the predisturbed state; therefore, DOE would not expect adverse impacts to the scenic value of the area. Site restoration would occur about 100 years earlier than under the Proposed Action.

7.1.11 UTILITIES, ENERGY, AND MATERIALS

Decommissioning and reclamation activities would consume electricity, diesel fuel, and gasoline. Much equipment and many materials would be salvaged and recycled. DOE would recycle buildings as practicable. After the site closed, minimal surveillance activities would require some electricity and gasoline. The No-Action Alternative would not adversely affect the utility, energy, or material resources of the region.

7.1.12 WASTE MANAGEMENT

The decommissioning and reclamation of the Yucca Mountain site would generate some waste requiring disposal, including sanitary sewage, sanitary and industrial solid waste, small amounts of demolition debris, and very small amounts of hazardous waste. DOE would dispose of the wastes as it has during the site characterization activities.

DOE would minimize waste generation by salvaging most of the equipment and many materials and redistributing them to other DOE sites or selling them at public auction. Remaining chemical supplies would be redistributed through the DOE excess program, which collects equipment and materials no longer in use for reassignment to other DOE sites or Federal facilities, donation to state governments, or sale to the public. DOE would preserve, rather than demolish, certain facilities that could be useful in the future, such as the electrical distribution and water supply systems. Sanitary sewage would be disposed of in the onsite septic system. At the end of reclamation activities, DOE would cap the inlets to the septic system and leave the system in place. DOE would dispose of sanitary and industrial solid waste and demolition debris in existing Nevada Test Site landfills, where disposal capacity would be available for about 70 years (DIRS 101803-DOE 1995, p. 8).

7.1.13 ENVIRONMENTAL JUSTICE

An examination of analyses from other technical disciplines associated with terminating characterization and construction activities at Yucca Mountain and decommissioning and reclaiming the site shows no potential for large impacts in areas other than cultural resources and socioeconomics. The cultural resources analysis identified the possibility that increased public access (if roads were left open and site boundaries were not secure) could threaten the integrity of archaeological sites and resources important to Native Americans. The socioeconomic analysis identified a potential loss of as many as 4,700 jobs (see Section 7.1.6).

Disproportionate impacts to minority or low-income populations from potential job losses would not be expected because there is no reason to believe that minority or low-income employees would be any more likely to be affected by job loss.

7.1.14 TRAFFIC AND TRANSPORTATION

Fatalities from project-related traffic would be unlikely during decommissioning and reclamation. As a gauge of the probability of 1 fatality, decommissioning and reclamation activities would require about 1 year to complete, or about one-fifth of the time to construct the repository. The analysis in Appendix J estimated less than 0.7 fatality from traffic accidents during repository construction, so less than 0.15 traffic fatality would be likely during decommissioning and reclamation (see Appendix J, Tables J-64 and J-65, for details).

7.1.15 SABOTAGE

There would be no nuclear materials at the Yucca Mountain site, so sabotage concerns would not be pertinent.

7.2 Commercial and DOE Sites

This section analyzes short- and long-term impacts of continued storage of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites for 10,000 years (the period considered for the Proposed Action). The analysis includes No-Action Scenarios 1 and 2.

The following paragraphs discuss short-term impacts under No-Action Scenario 1. Because the analysis assumed that all sites would maintain institutional control for the first approximately 100 years, the short-term impacts for Scenarios 1 and 2 would be the same. For consistency with the Proposed Action, this analysis assumed the No-Action scenarios would begin in 2002. This analysis considered the Idaho National Engineering and Environmental Laboratory to be a site for naval spent nuclear fuel because the Laboratory stores such fuel.

Under the No-Action Alternative, commercial utilities would manage their spent nuclear fuel at 72 facilities. DOE would manage its spent nuclear fuel and high-level radioactive waste at five facilities (the Hanford Site, the Idaho National Engineering and Environmental Laboratory, Fort St. Vrain (spent nuclear fuel only) the West Valley Demonstration Project (high-level radioactive waste only), and the Savannah River Site). The No-Action analysis evaluated the DOE spent nuclear fuel and high-level radioactive waste at existing sites or at sites where existing Records of Decisions have placed or will place these materials. For example, the Record of Decision (60 FR 18589, April 12, 1995) for the Final Supplemental Environmental Impact Statement, Defense Waste Processing Facility (DIRS 103191-DOE 1994, all) decided to complete construction and operate the Defense Waste Processing Facility and associated facilities at the Savannah River Site to pretreat, immobilize, and store high-level radioactive waste. Similarly, the Hanford Site Final Environmental Impact Statement for the Tank Waste Remediation System (DIRS 103214-DOE 1996, all) identified as the preferred alternative ex situ vitrification of high-level radioactive waste with onsite storage until final disposition in a geologic repository. For DOE spent nuclear fuel, the Record of Decision (60 FR 28680, June 1, 1995) for the Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (DIRS 101802-DOE 1995, all) decided that Hanford production reactor fuel would remain at the Hanford Site; aluminum-clad fuel would be consolidated at the Savannah River Site; and non-aluminum-clad fuels (including spent nuclear fuel from the Fort St. Vrain reactor and naval spent nuclear fuel) would be transferred to the Idaho National Engineering and Environmental Laboratory. Therefore, the analysis evaluated DOE aluminum-clad spent nuclear fuel at the Savannah River Site and DOE non-aluminum-clad fuel at the Idaho National Engineering and Environmental Laboratory; most of the Fort St. Vrain spent nuclear fuel at the Colorado generating site; and high-level radioactive waste at the generating sites (the West Valley Demonstration Project, the Idaho National Engineering and Environmental Laboratory, the Hanford Site, and the Savannah River Site).

The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would be treated, packaged, and stored in a condition ready for shipment to a repository. The amount (inventory) of spent nuclear fuel and high-level radioactive waste considered in this analysis would be the same as that for the Proposed Action—70,000 metric tons consisting of 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, 8,315 canisters of solidified high-level radioactive waste. The 70,000 MTHM would include surplus plutonium in the form of mixed-oxide fuel and immobilized plutonium. In addition, DOE recognizes that more than 107,000 MTHM of commercial and DOE spent nuclear fuel and more than 22,000 canisters of high-level radioactive waste could require storage if a disposal site is not available. Section 7.3 describes the assumptions and analytical methods used to estimate impacts for the total projected inventory of spent nuclear fuel and high-level radioactive waste, referred to as Inventory Module 1, and evaluates the potential impacts of the continued storage of the total projected inventory of commercial and DOE spent nuclear fuel and high-level radioactive waste.

Storage Packages and Facilities at Commercial and DOE Sites

A number of designs for storage packages and facilities at the commercial and DOE sites would provide adequate protection from the environment for packages containing spent nuclear fuel and high-level radioactive waste. Because it has not selected specific designs for most locations, DOE selected a representative range of commercial and DOE designs for analysis, as described in the following paragraphs. In addition, for purposes of analysis, the No-Action Alternative assumed that the commercial and DOE sites have sufficient land to construct the initial and replacement storage facilities and that the initial construction of all dry storage facilities would be complete and the facilities filled by 2002.

Spent Nuclear Fuel Storage Facilities

Most commercial sites currently store their spent nuclear fuel in water-filled basins (fuel pools) at the reactor sites. Because they have inadequate storage space, some commercial sites have built what are called *independent spent fuel storage installations,* in which they store dry spent nuclear fuel above ground in metal casks or in welded canisters inside reinforced concrete storage modules. Other commercial sites plan to build independent spent fuel storage installations so they can proceed with the decommissioning of their nuclear plants and termination of their operating licenses (for example, the Rancho Seco and Trojan plants). Because commercial sites could elect to continue operations until their fuel pools became full and then cease operations, the EIS analysis initially considered ongoing wet storage in existing fuel pools to be a potentially viable option for spent nuclear fuel storage. However, dry storage is almost certainly the preferred option for long-term spent fuel storage at commercial sites for the following reasons (DIRS 101899-NRC 1996, pp. 6-76 and 6-85):

- Dry storage is a safe economical method of storage.
- Fuel rods in dry storage are likely to be environmentally secure for long periods.
- Dry storage generates minimal, if any, low-level radioactive waste.
- Dry storage units are simpler and easier to maintain.

Accordingly, this EIS assumes that all commercial spent nuclear fuel would be stored in dry configurations in independent spent fuel storage installations at existing locations (Figure 7-2 is a photograph of a typical independent spent fuel storage installation). This assumption includes spent nuclear fuel at sites that no longer have operating nuclear reactors. Although most utilities and DOE have not constructed independent spent fuel storage installations or designed dry storage containers, this analysis evaluates the impacts of storing all commercial and some DOE spent nuclear fuel in horizontal concrete storage modules (Figure 7-3) on a concrete pad at the ground surface. Concrete storage modules have openings that allow outside air to circulate and remove the heat of radioactive decay. The analysis assumed that spent nuclear fuel from both pressurized-water and boiling-water reactors would be stored in a dry storage canister inside the concrete storage module. Figure 7-4 shows a typical dry storage canister, which would consist of a stainless-steel outer shell, welded end plugs, pressurized helium internal environment, and criticality-safe geometry for 24 pressurized-water or 52 boiling-water reactor fuel assemblies.

The combination of the dry storage canister and the concrete storage module would provide safe storage of spent nuclear fuel as long as the fuel and storage facilities were maintained properly. The reinforced concrete storage module would provide shielding against the radiation emitted by the spent nuclear fuel. In addition, the concrete storage module would provide protection from damage resulting from accidents such as aircraft crashes and from natural hazard phenomena such as earthquakes or tornadoes.

This analysis assumed that DOE would store dry spent nuclear fuel at the Savannah River Site, the Idaho National Engineering and Environmental Laboratory, and Fort St. Vrain in stainless-steel canisters inside above-grade reinforced concrete storage modules. In addition, it assumed that the design of DOE above-ground spent nuclear fuel storage facilities would be similar to the independent spent fuel storage installations at commercial sites.

The analysis assumed that DOE would store spent nuclear fuel at Hanford in a dry cask in below-grade storage facilities. DOE would store Hanford N-Reactor fuel in the Canister Storage Building, which would consist of three below-grade concrete vaults with air plenums for natural convective cooling. The vaults would contain vertical storage tubes made of carbon steel. Each storage tube, which would hold two spent nuclear fuel canisters, would be sealed with a shield plug. DOE would cover the vaults with a structural steel shelter.

High-Level Radioactive Waste Storage Facilities

With one exception, this analysis assumed that DOE would store solidified high-level radioactive waste in dry below-grade, high-level radioactive waste storage facilities (Figure 7-5). At the West Valley Demonstration Project, the analysis assumed that DOE would use a dry storage system similar to a commercial independent spent nuclear fuel storage installation for high-level radioactive waste.

A high-level radioactive waste storage facility consists of four areas: below-grade storage vaults, an operating area above the vaults, air inlet shafts, and air exhaust shafts. The canister cavities are galvanized-steel large-diameter pipe sections arranged in a grid. Canister casings are supported by a concrete base mat. Space between the pipes is filled with overlapping horizontally-stepped steel plates that direct most of the ventilation air through the storage cavities.

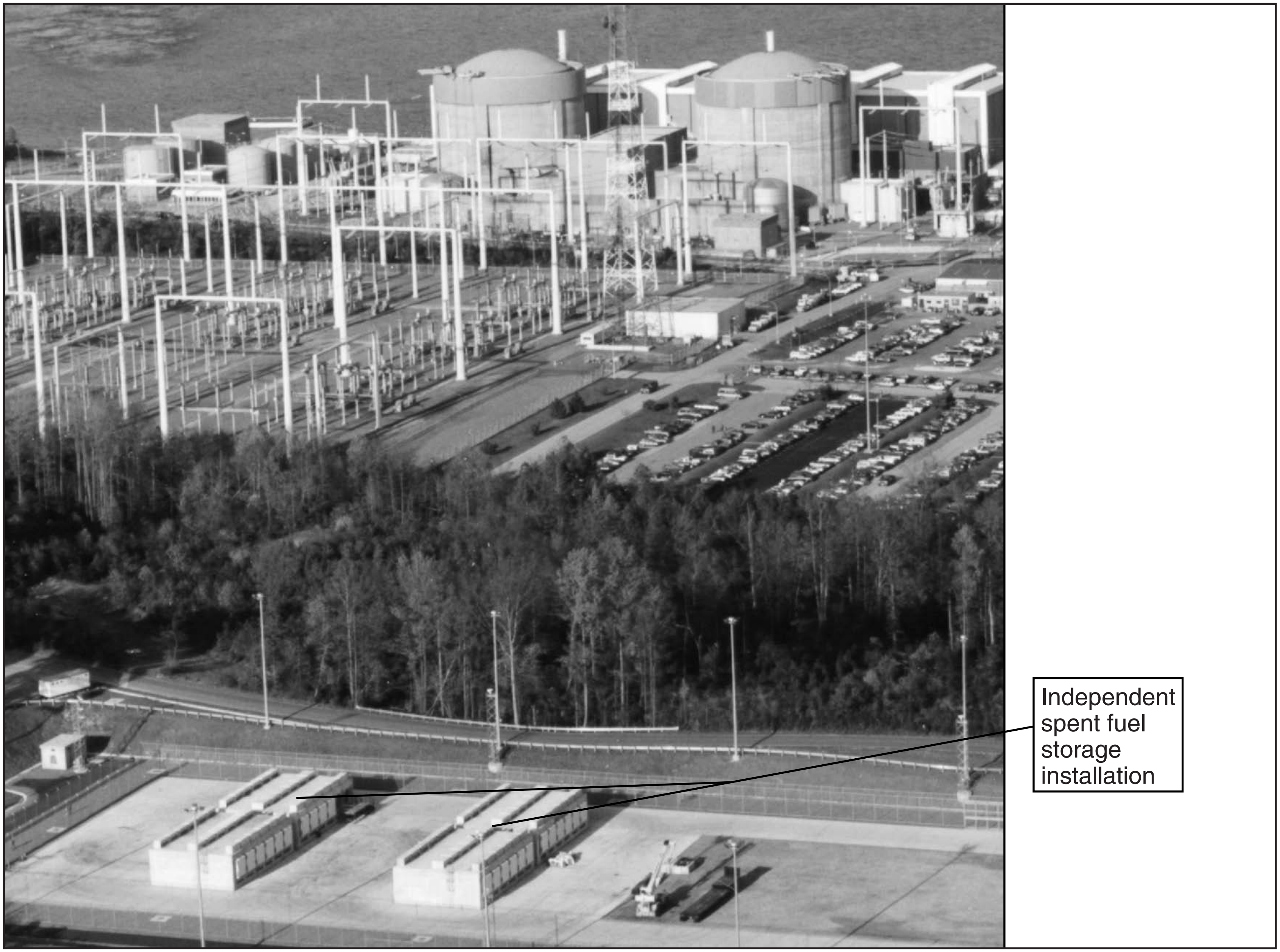
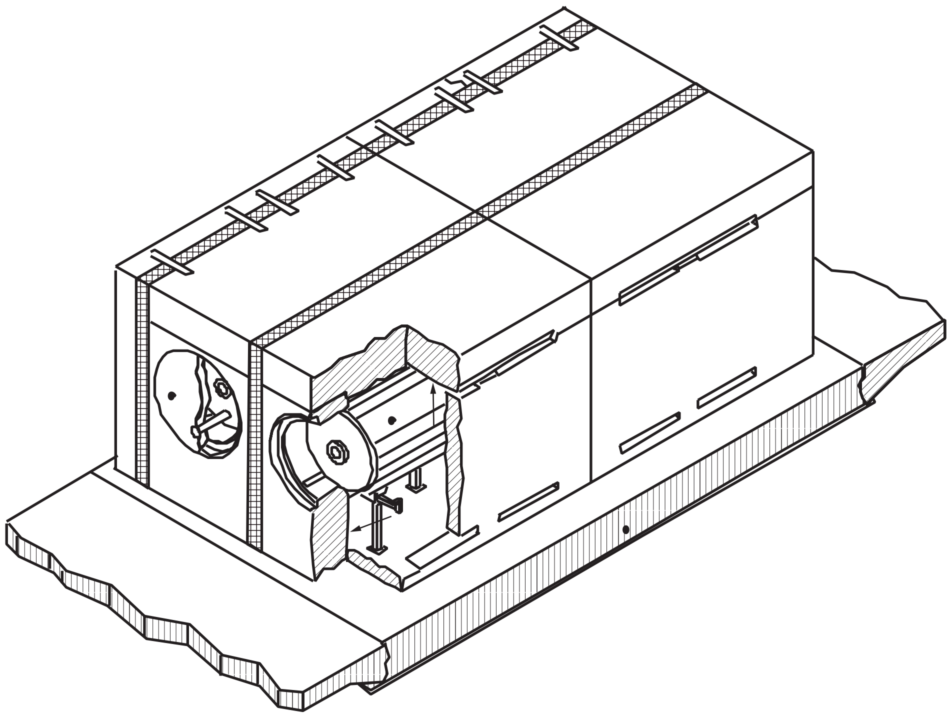


Figure 7-2. Typical independent spent fuel storage installation.



Source: Modified from DIRS 101910-Poe (1998, p. 1-2).

Figure 7-3. Spent nuclear fuel concrete storage module.

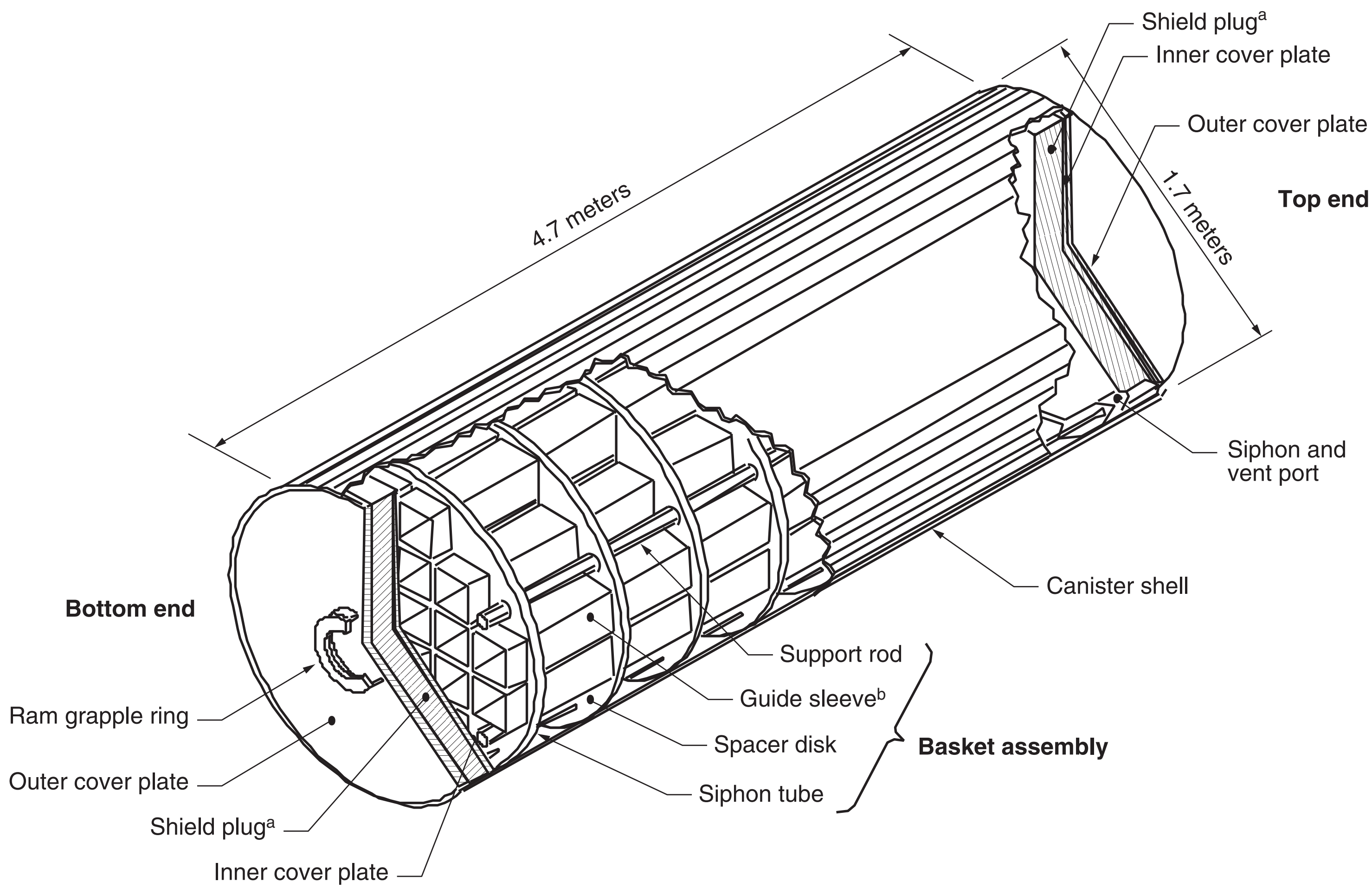
The below-grade storage vault would be below the operating floor, which would be slightly above grade. The storage vault would be designed to withstand earthquakes and tornadoes. In addition, the operating area would be enclosed by a metal building, which would provide weather protection and prevent the infiltration of precipitation. The storage vault would be designed to store the canisters and protect the operating personnel, the public, and the environment for as long as the facilities were maintained. The surrounding earth, concrete walls, and a concrete deck that would form the floor of the operating area would provide radiation shielding. Canister cavities would have individual precast concrete plugs.

Each vault would have an air inlet, air exhaust, and air passage cells. The storage facility's ventilation system would remove the heat of radioactive decay from around the canisters. The exhaust air could pass through high-efficiency particulate air filters before it discharged to the atmosphere through a stack. As an alternative, natural convection cooling without filters could be used. The oversized diameter of the pipe storage cavities would allow air to pass around each cavity.

7.2.1 NO-ACTION SCENARIO 1

Under Scenario 1, 72 commercial sites and 5 DOE sites would store spent nuclear fuel and high-level radioactive waste for 10,000 years. Institutional control, which would be maintained for the entire 10,000-year period, would ensure regular maintenance and continuous monitoring at these facilities that would safeguard the health and safety of facility employees, surrounding communities, and the environment. The spent nuclear fuel and immobilized high-level radioactive waste would be *inert* material encased in durable, robust packaging and stored in above- or below-grade concrete facilities. Release of contaminants to the ground, air, or water would not be expected during routine operations.

DOE and commercial utility workers would perform all maintenance including routine industrial maintenance and maintenance unique to a nuclear materials storage facility under standard operating



All materials 304 stainless steel except as noted.

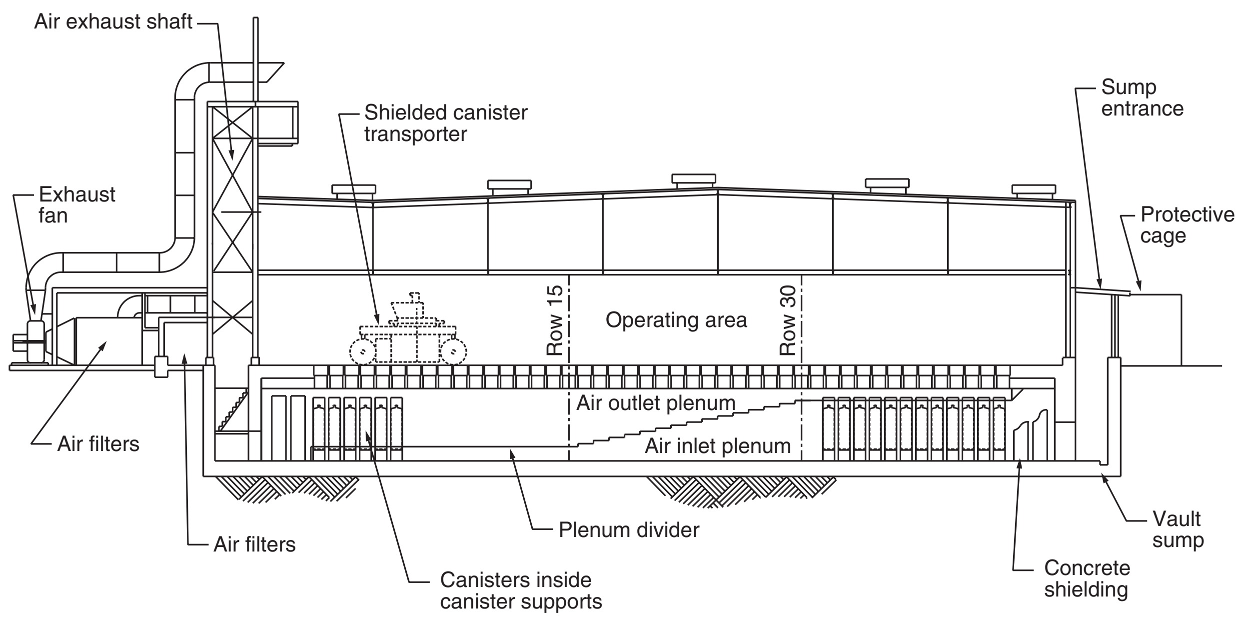
a. Shield plug would be lead.

b. Borated neutron absorber plate for boiling-water reactor spent nuclear fuel assemblies.

To convert meters to feet, multiply by 3.2808.

Source: Modified from DIRS 101910-Poe (1998, p. 1-5).

Figure 7-4. Spent nuclear fuel dry storage canister.



Source: Derived from DIRS 101910-Poe (1998, pp. 4-7, 4-8, and 4-11).

Figure 7-5. Conceptual design for solidified high-level radioactive waste storage facility.

procedures and best management practices to ensure minimal releases of contaminants (industrial and nuclear) to the environment and minimal exposures to workers and the public. This analysis assumed that DOE would manage these facilities in accordance with Departmental rules (10 CFR Part 835) and Orders (see Chapter 11) and that commercial facilities would meet applicable environmental safety and health requirements. It also assumed that storage facilities would require replacement every 100 years and that they would undergo major repairs halfway through the first 100-year cycle. Chapter 2, Section 2.2, provides additional information pertaining to Scenario 1. The following sections treat short- and long-term impacts separately where appropriate.

7.2.1.1 Land Use and Ownership

The storage facilities for spent nuclear fuel and high-level radioactive waste would be at commercial and DOE sites. Facilities would require replacement every 100 years (beginning about 2110), which would occur on land immediately adjacent to the existing facilities. The land required for a storage facility typically would be a few acres, a small percentage of the land available at current sites. An environmental assessment of an independent spent fuel storage installation determined that operation of the facility would require no more land than it occupied (DIRS 101898-NRC 1991, p. 20).

At the end of each 100-year cycle, a new facility constructed next to the old one would contain the spent nuclear fuel or high-level radioactive waste. The old facility would be demolished and the land reclaimed and maintained for the next 100 years. By alternating the facility between two adjacent locations, minimal land would be required.

Storage facilities would be on land owned by either DOE or a utility. Storage at these sites would be unlikely to affect land use and ownership.

7.2.1.2 Air Quality

As a part of routine operations, best management practices and effective monitoring procedures would ensure that any contaminant releases to the air would be minimal and would not exceed current regulatory limits (40 CFR Part 61 for hazardous air pollutant emissions and Part 50 for air quality standards). Therefore, the No-Action Alternative would not produce adverse impacts to air quality during routine operations.

The analysis assumed that the storage facilities would require complete replacement every 100 years. During the construction of the replacement facility, exhaust from construction vehicles would temporarily increase local levels of hydrocarbons, carbon monoxide, and oxides of nitrogen, but these and other atmospheric pollutants would be likely to remain within National Ambient Air Quality Standards (see Chapter 3, Table 3-5). Temporary increases in particulate matter would result from these construction activities. Mitigation measures such as watering unpaved roads would limit the generation of fugitive dust. In addition, after replacement the old site would be seeded, graveled, or paved to reduce air emissions. Detrimental air quality impacts would be short-term, minimal, and transient.

Very small air quality impacts would be likely from repackaging materials removed from dry storage containers that could degrade to the point that they no longer met licensing requirements; these impacts were not included in the overall impact estimates. Long-term dry storage canister degradation would be highly variable and difficult to estimate from site to site, and DOE did not want to overestimate the accompanying air quality impacts from repackaging.

7.2.1.3 Hydrology

7.2.1.3.1 *Surface Water*

As part of routine operations, best management practices such as stormwater pollution prevention plans and stormwater holding ponds would ensure that, in the unlikely event of an inadvertent contaminant release, contaminants did not reach surface-water systems. Effective monitoring procedures would ensure that operation of the facility did not adversely affect surface waters and that no discharges would contaminate surface waters in excess of drinking water regulatory limits (40 CFR Part 141). Detention basins would capture all runoff, which would be monitored for contamination and treated, as necessary, before it was released to the environment. If the storage facility required active cooling systems, those systems would be designed to contain any inadvertent spill of operating fluids so they could not reach the environment. Therefore, No-Action Scenario 1 would be unlikely to produce adverse impacts to surface-water quality during routine operations.

During construction of the replacement storage facilities, adherence to stormwater pollution prevention plans would ensure that cleared areas and exposed earth would be seeded, graveled, or paved to control runoff and minimize soil erosion that could adversely affect surface-water quality. Surface-water runoff detention ponds would prevent eroded material from entering surface water systems. These erosion control practices would ensure minimal impacts to surface-water quality during construction. To prevent contamination from construction equipment, workers would monitor the equipment for leaks. Inadvertent spills of industrial fluids would be contained and cleaned up in accordance with established spill prevention and cleanup plans. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to surface-water quality during construction operations.

7.2.1.3.2 *Groundwater*

During routine operations, best management practices such as spill prevention and cleanup plans and procedures and effective monitoring procedures would ensure that inadvertent contaminant releases would not reach groundwater. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to groundwater quality during routine operations.

The spent nuclear fuel storage facilities at the commercial sites would be surface structures with shallow foundations such that their construction would not disturb groundwater systems. Some DOE storage facilities would be subsurface structures for which construction might require minimal dewatering of the groundwater aquifer. However, the area occupied by the structure would be small in relation to the size of the aquifer, so no adverse impacts would be likely to result from dewatering activities.

Excavations would remove the soil buffer between surface activities and groundwater, increasing the likelihood of groundwater contamination from an inadvertent spill or leak of construction-related fluids (for example, diesel fuel, oil, hydraulic fluids). Construction activities would be as described above for surface water; thus, the penetration of spilled construction fluids to groundwater would be unlikely. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to groundwater quality during construction operations.

7.2.1.4 Biological Resources and Soils

Impacts to biological resources or soils from the construction and operation of spent nuclear fuel and high-level radioactive waste storage facilities would be minimal. Heat from the storage modules would not affect nearby vegetation. The storage facilities would be fenced to keep wildlife out. However, some smaller animal species could take advantage of the warm air from storage facility vents in winter, and individual animals could receive adverse impacts, including death, from direct exposure to radiation. As the heat of radioactive decay decreased, these sites would become less attractive to animals seeking warm environments.

The storage facilities would have a minimal effect on the soil. Because the operating and decommissioned facilities would alternate between two locations, the amount of soil disturbed by construction would be very small. By adhering to best management practices and standard operating procedures, DOE expects that spills would be minimal. A spill would be contained and cleaned up immediately, thus minimizing the area of soil affected.

7.2.1.5 Cultural Resources

Replacement spent nuclear fuel and high-level radioactive waste storage facilities would generally be on undeveloped land in rural areas owned by DOE or the commercial utilities. The size of each facility and supporting infrastructure would be small enough to avoid known cultural resources. If construction activities uncovered previously unknown archaeological sites, human remains, or funerary objects, DOE or the commercial utility would comply with Executive Orders and Federal and state regulations for the protection of cultural resources (see Chapter 11, Section 11.2.5, for details). Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to cultural resources during construction and operations.

7.2.1.6 Socioeconomics

Storage facilities for spent nuclear fuel and high-level radioactive waste would be at existing DOE and commercial sites. A staff of about eight workers (two individuals on duty per shift, 24 hours per day) would monitor and maintain each facility (DIRS 104596-Orthen 1999, Table 2, p. 4). The analysis assumed that facilities would require replacement every 100 years, and that there would be a major facility repair halfway through the first 100-year cycle. Facility replacement every 100 years would require approximately 40 workers for 2 years (DIRS 104596-Orthen 1999, Table 2 and Table 6). Major repairs halfway through the first 100-year cycle would require about 40 workers for 1 year (DIRS 104596-Orthen 1999, Table 2 and Table 6).

Each of the 77 sites that stores spent nuclear fuel or high-level radioactive waste employs monitoring and maintenance personnel. Additional staffing for facility replacement [and the one-time major repair (see DIRS 104596-Orthen 1999, Tables 1 and 2)] would be temporary and comprise about 40 employees at a site during construction. (Construction of DOE facilities could require more workers, but the Department would have only five of these facilities reconstructed every 100 years.) This temporary increase in employment would be small in proportion to the existing workforces in affected communities. Therefore, the No-Action Alternative would be unlikely to have adverse effects on socioeconomic factors such as infrastructure and regional economy.

7.2.1.7 Occupational and Public Health and Safety

7.2.1.7.1 *Nonradiation Exposures*

Maintenance, repairs, repackaging, and construction at the storage facilities would be conducted in accordance with requirements of the Occupational Health and Safety Administration and National Institute of Occupational Safety and Health. Administrative controls and design features would minimize worker exposures to industrial nonradioactive hazardous materials during the construction and operation of the storage facilities so exposures would remain below hazardous levels.

7.2.1.7.2 *Industrial Hazards*

The industrial hazards evaluated were (1) total recordable injury and illness cases, (2) lost workday cases associated with workplace injuries and illnesses, and (3) workplace fatalities. The estimates of these traumas were based primarily on the staffing level of involved workers assigned to spent nuclear fuel and high-level radioactive waste management tasks, coupled with representative workplace loss indicators maintained by the Bureau of Labor Statistics (DIRS 148091-BLS 1998, all) or the DOE Computerized Accident/Incident Reporting System database (DIRS 147938-DOE 1999, all). Involved worker risk exposure estimates were based on crew sizes to determine the number of full-time equivalent work years assigned to construction and to operations, surveillance, and maintenance tasks. DOE used representative historic total recordable case, lost workday case, and fatality incident data to project the associated trauma incidence based on the number of workers and their job functions.

This analysis assumed that replacement facilities would be constructed every 100 years and that a major repair and upgrade of the initial facilities would be required once after the first 50 years. Impacts from decommissioning retired facilities were included as part of construction.

For the approximately 100-year construction and operation cycle (2002 to 2116), about 72,000 full-time equivalent work years of effort would be required to maintain and repair about 6,600 concrete storage modules and 4 below-grade storage vaults at the 72 commercial and 5 DOE sites (DIRS 104596-Orthen 1999, Tables 1, 6, and 7). Based on this level of effort, as listed in Table 7-5, about 2,300 industrial safety incidents would be likely, resulting in about 1,000 lost workday cases and 2 fatalities (an average of 1 fatality every 50 years).

In addition, for the remaining 9,900 years, Table 7-5 indicates about 290,000 estimated industrial safety incidents, of which about 130,000 would be lost workday cases and 320 would involve fatalities (an average of 1 fatality every 30 years or about one every 2,500 years at each of the 77 sites). Surveillance tasks would consume 94 percent of the total worker level of effort, construction tasks would consume nearly all of the remaining 6 percent, and operations tasks would consume less than 0.001 percent (DIRS 104596-Orthen 1999, Table 2).

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7.2.1.7.3 *Radiation Exposures*

For Scenario 1, the analysis assumed that the facilities would undergo major repairs once during the first 100 years and would be replaced every 100 years thereafter. Very low exposures to future construction workers would occur as they built replacement facilities adjacent to the existing facilities. Transferring the dry storage canisters from old to new concrete storage modules would result in some additional exposures to workers.

Table 7-5. Estimated industrial safety impacts at commercial and DOE sites during the first 100 years and the remaining 9,900 years of the 10,000-year analysis period under Scenario 1.[a]

Industrial safety impacts	Short-term[b] (100 years) construction and operation	Long-term (9,900 years)[c] construction and operation
Total recordable cases	2,300	290,000
Lost workday cases	1,000	130,000
Fatalities	2.4	320

a. Source: DIRS 104596-Orthen (1999, Tables 6 and 7).
b. The estimated impacts would result from a single 100-year period of storage module construction (renovation), operation, surveillance, and repair.
c. Period from 100 to 10,000 years.

During normal operations, facility workers would be exposed to low levels of external radiation while performing routine surveillance and monitoring activities, changing high-efficiency particulate air filters on ventilation systems (for high-level radioactive waste storage facilities), transferring dry storage canisters between concrete storage modules, and maintaining and repairing the facilities. In addition, individuals employed at the nearby nuclear powerplant but not directly involved with activities at the spent nuclear fuel storage facility (noninvolved workers) would be exposed to low levels of external radiation emanating from the filled concrete storage modules. Activities within the facility boundaries would be in accordance with DOE or Nuclear Regulatory Commission guidelines for nuclear facility worker protection (10 CFR Part 835 and 10 CFR Part 20). Table 7-6 lists estimated maximum annual individual doses and the total average collective dose for worker populations during the 100- and 10,000-year analysis periods for commercial and DOE sites.

The Scenario 1 analysis treated the dose rates from DOE spent nuclear fuel as equivalent to commercial spent nuclear fuel on a volume basis. This simplifying assumption had minimal effect on estimated individual and population doses because of the relatively small quantities of DOE spent nuclear fuel (less than 10 percent of the total) and essentially equal radiation exposure rates in comparison to commercial spent nuclear fuel on a volume basis. The analysis separated the calculation of dose rates from high-level radioactive waste because of the difference in source materials.

For Scenario 1, dose rates from high-level radioactive waste were estimated based on the isotopic distributions provided in Appendix A, Tables A-28, A-29, and A-30. As with commercial and DOE spent nuclear fuel, estimated dose rates to facility workers considered shielding provided by the concrete facility structures and decay over the 10,000-year analysis period. However, because of the relatively large distance from the storage facilities to the site boundary [typically more than 3 kilometers (2 miles) at the Hanford Site, the Idaho National Engineering and Environmental Laboratory, and the Savannah River Site], doses to the public were not included. Although the distance to the site boundary at the West Valley Demonstration Project is less than 3 kilometers, not including public exposures from above-grade storage facilities would result in a very small underestimation of impacts because DOE stores only about 4 percent of the high-level radioactive waste at that facility.

Very small air quality impacts would be likely from repackaging materials removed from dry storage containers that could degrade to the point that they no longer met licensing requirements. However, overall impact estimates did not include these impacts because long-term dry storage canister degradation would be highly variable and difficult to estimate from site to site, and DOE did not want to overestimate the accompanying air quality impacts from repackaging.

Table 7-6. Estimated radiological impacts (dose) and consequences from construction and routine operation of commercial and DOE spent nuclear fuel and high-level radioactive waste storage facilities – Scenario 1.[a]

Receptor	Short-term (100 years) construction and operation	Long-term (9,900 years) construction[b] and operation
Population[c]		
MEI[d] (millirem per year)	0.20	0.06
Dose[e] (person-rem)	810	5,200
LCFs[f]	0.41	2.6
Involved worker[g]		
MEI[h] (millirem per year)	170	50
Dose[e] (person-rem)	2,600	24,000
LCFs[f]	1.0	10
Noninvolved workers[i]		
MEI[j] (millirem per year)	13	0[k]
Dose[e] (person-rem)	36,000	0[k]
LCFs[f]	15	0[k]

a. Source: Adapted from DIRS 101898-NRC (1991, all); DIRS 104596-Orthen (1999, all).
b. Assumes construction of 6,600 concrete storage modules and three below-grade vaults at 77 sites every 100 years (DIRS 104596-Orthen 1999, Table 1).
c. Members of the general public living within 3 kilometers (2 miles) of the facilities; estimated to be 140,000 over the first approximately 100 years and approximately 14 million over the duration of the analysis period [estimated using DIRS 102204-Humphreys, Rollstin, and Ridgely (1997, all)].
d. MEI = maximally exposed individual; assumed to be approximately 1.4 kilometers (0.8 mile) from the center of the storage facility (DIRS 101898-NRC 1991, p. 22).
e. Estimated doses account for radioactive decay.
f. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0004 and 0.0005 latent cancer fatality per rem for workers and members of the public, respectively (DIRS 101857-NCRP 1993, p. 112), and a life expectancy of 70 years for a member of the public and a 50-year career for workers.
g. Involved workers would be those directly associated with construction and operation activities (DIRS 101898-NRC 1991, pp. 23 to 25). For this analysis, the involved worker population would be approximately 1,400 individuals (700 individuals at any one time) at 77 sites over 100 years (DIRS 104596-Orthen 1999, Table 6). This population would grow to about 160,000 over 10,000 years.
h. Based on maximum construction dose rate of 0.11 millirem per hour and 1,500 hours per year (DIRS 101898-NRC 1991, p. 23).
i. Noninvolved workers would be employed at the powerplant but would not be associated with facility construction or operation. For this analysis, the noninvolved worker population would be 80,000 individuals who would receive exposures until the powerplants were decommissioned (50 years).
j. Based on a projected area workforce of 1,200 and an average estimated annual dose of 16 person-rem (DIRS 101898-NRC 1991, p. 24).
k. During this period the powerplants would have ended operation, so there would be no noninvolved workers.

As listed in Table 7-6, the estimated dose to the hypothetical maximally exposed offsite individual during the short-term operational period between 2002 and 2116 would be about 0.20 millirem per year (DIRS 101898-NRC 1991, p. 22). For the remaining 9,900 years of the analysis period (long-term impacts), the dose to the hypothetical maximally exposed individual would decrease to about 0.060 millirem per year because of radioactive decay of the source material. During about the first 100 years, the dose (accounting for radioactive decay) could result over a 70-year lifetime of exposure in an increase of 0.0000043 in the lifetime risk of contracting a fatal cancer, an increase over the lifetime natural fatal cancer incidence rate of 0.0018 percent. During the remaining 9,900 years of the analysis period, the dose could result in an increase of 0.0000013 in the lifetime risk of contracting a fatal cancer, an increase of 0.00055 percent over the lifetime natural fatal cancer incidence rate.

Based on the Nuclear Regulatory Commission computer program SECPOP (DIRS 102204-Humphreys, Rollstin, and Ridgely 1997, all), in 1990 approximately 100,000 people lived within 3 kilometers (2 miles) of some type of commercial nuclear facility (DIRS 101917-Rollins 1998, p. 9). Over the 100-year analysis period, the total number of people that would be exposed would be approximately 140,000 because more than one 70-year lifetime would be spanned during the 100-year period. As listed in Table 7-6, between 2002 and 2116 these people would be likely to receive a total collective dose of 810 person-rem.

Long-term doses and latent cancer fatalities for the approximately 9,900-year period between 2116 and 12010 were based on the assumptions described above, with a few notable exceptions. Impacts to noninvolved workers were not calculated because all of the nuclear powerplants would be closed by the beginning of this period. In addition, the total exposed populations of workers and the public would increase by a factor of 100 above the 100-year exposed population because this period would span 140 lifetimes of 70 years. As noted above, for the first 100 years of operation approximately 140,000 people living within 3 kilometers (2 miles) of the storage facilities (100,000 people multiplied by 1.4 consecutive 70-year average human lifetimes [the average number of 70-year lifetimes in 100 years]) would be exposed to external radiation. Over 10,000 years the exposed population would total approximately 14 million people. Therefore, for the period between 2116 and 12010, the offsite population would receive an estimated total collective dose of 5,200 person-rem (adjusted for radioactive decay).

Population statistics indicate that in 1990 cancer caused about 24 percent of the deaths in the United States (DIRS 153066-Murphy 2000, p. 5). If this percentage of deaths from cancer continued, about 24 people out of every 100 in the U.S. population would contract a fatal cancer from some cause. For approximately the first 100 years, the radiation exposure dose from the storage facilities could cause an additional 0.41 latent cancer fatality in the surrounding populations. This would be in addition to about 33,000 cancer fatalities that would be likely in the exposed population of 140,000 from all other causes, or an increase in the natural incidence rate of 0.0012 percent. For the remaining 9,900 years of the analysis, the radiation exposure dose from the storage facilities could result in an additional 2.6 latent cancer fatalities in the surrounding populations. This would be in addition to about 3.3 million cancer fatalities that would be likely to occur in the exposed population of 14 million, or an increase of 0.000079 percent over the natural incidence rate.

The analysis assumed the maximally exposed individual in the involved worker population would be involved in constructing and loading replacement facilities. Assuming a maximum dose rate of 0.11 millirem per hour and an average exposure time of 1,500 hours per year, this construction worker would receive about 170 millirem per year. During about the first 100 years, the dose could result (over 3 years of construction) in an increase in the lifetime risk of contracting a fatal cancer of 0.00020, an increase of 0.090 percent over the national fatal cancer incidence rate of about 24 percent. During the remaining 9,900 years of the analysis period, the dose could result (over 3 years of construction) in an increase in the risk of contracting a fatal cancer of 0.000060, an increase of 0.030 percent over the natural fatal cancer incidence rate.

For the involved worker population of 1,400 individuals, approximately 330 would be likely to contract a fatal cancer from some cause other than occupational exposure. In this population (during the first 100 years), the collective dose of 2,600 person-rem (correcting for decay) between 2002 and 2116 could result in about 1 additional latent cancer fatality (DIRS 104596-Orthen 1999, Table 6), an increase of 0.33 percent over the natural incidence rate of fatal cancers from all causes. During the remaining 9,900 years of the analysis period, the approximately 160,000 involved workers would receive a collective dose of 24,000 person-rem (corrected for decay). This dose could result in an additional 10 latent cancer fatalities (about 1 every 1,000 years during the 9,900-year analysis period), an increase of 0.027 percent over the natural incidence rate of fatal cancers.

Noninvolved workers would be those employed at an operating nuclear powerplant but not directly involved with the day-to-day operation of the spent nuclear fuel storage facility. The analysis assumed that noninvolved workers (about 800 for each of the approximately 100 reactor units at 72 commercial sites) would be generally several hundred to several thousand feet from the storage facilities. In addition, it assumed that noninvolved workers would be at the sites until 2052 (that is, for 50 years).

The Nuclear Regulatory Commission estimated that the dose to noninvolved workers at a nuclear powerplant from a fully loaded independent spent fuel storage installation would be about 16 person-rem per year (DIRS 101898-NRC 1991, p. 24) for the protected-area workforce of 1,200 individuals (DIRS 101898-NRC 1991, p. 26) at the two-unit station of Calvert Cliffs. This collective dose would result in an average maximum dose to the noninvolved worker of 13 millirem per year. Over a 50-year career, this exposure (accounting for radioactive decay) could result in an increase in lifetime risk of contracting a fatal cancer of 0.00018, an increase of 0.077 percent over the natural incidence rate of fatal cancers.

The analysis made the conservative assumption that there are about 80,000 powerplant workers in the United States (800 per reactor unit and about 100 units currently operating), and that these workers would receive radiation exposure from the adjacent storage facilities until powerplant decommissioning, which the analysis assumed will occur in 2052. In the total noninvolved worker population of 80,000 powerplant workers (all sites), the collective dose of 36,000 person-rem (accounting for radioactive decay) between 2002 and 2116 could result in 15 additional latent cancer fatalities. This would be about 0.079 percent more than the 19,000 cancer fatalities that would be likely to occur from all other causes in the same worker population.

Figure 7-6 shows the calculated dose to these populations as a function of time, expressed as 70-year doses. For the noninvolved worker population, the population dose would occur during only the first 70-year interval. The public dose would decrease over time due to the inherent radioactive decay that will occur in the spent nuclear fuel and high-level radioactive waste as time elapses. Many of the radioactive constituents have half-lives substantially less than 10,000 years; therefore, it is likely that the dose to the public would decrease noticeably over time. The involved worker population dose also would decrease over time because of radioactive decay. The involved worker dose would fluctuate as new concrete storage modules were constructed and radioactive material was transferred from the old to the new modules every 100 years. During those 70-year intervals in which construction and transfer would occur, the dose would be higher; the dose would be lower during those 70-year intervals when these activities did not occur.

Because no liquid or airborne effluents would emanate from the storage facilities, direct and air-scattered radiation would comprise the total source of radiation exposure to the public. For populations more than 3 kilometers (2 miles) from the facilities (as is the case for most DOE facilities), direct and air-scattered external radiation exposure would be small (DIRS 101898-NRC 1991, p. 22).

7.2.1.8 Accidents

For Scenario 1, activities at each facility would include surveillance, inspection, maintenance, and equipment replacement, when required. The facilities and the associated systems, which the Nuclear Regulatory Commission would license, would have certain required features. License requirements would include isolation of the stored material from the environment and its protection from severe accident conditions. The Nuclear Regulatory Commission requires an extensive safety analysis that considers the impacts of plausible accident-initiating events such as earthquake, fire, high wind, and tornado. In addition, the license would specify that facility design requirements include features to provide protection from the impacts of severe natural events. These requirements and analyses must demonstrate that the facilities could withstand the most severe wind loading (tornado winds and tornado-generated missiles) and flooding from the Probable Maximum Hurricane with minimal release of radioactive material. This analysis assumed indefinite maintenance of these features for the storage facilities.

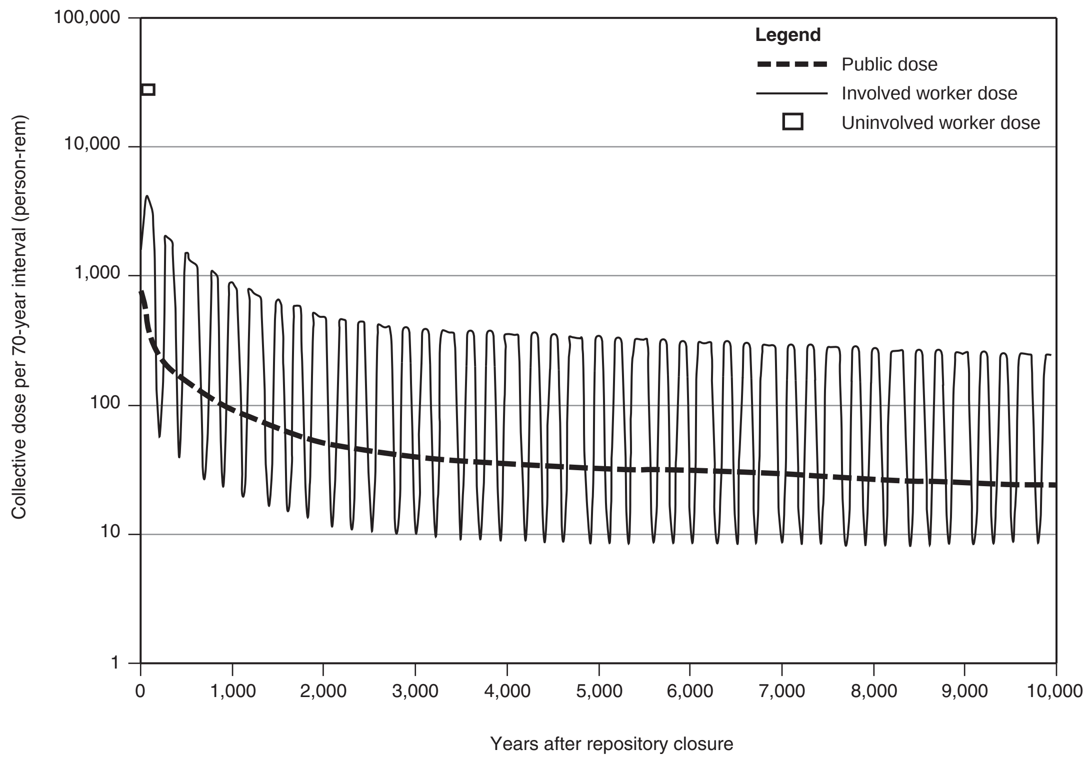

Figure 7-6. Collective dose for 70-year intervals for No-Action Scenario 1.

DOE performed an analysis to identify the kinds of events that could lead to releases of radioactive material to the environment prior to degradation of concrete storage modules and found none. The two events determined to be the most challenging to the integrity of the concrete storage modules would be the crash of an aircraft into the storage facility and a severe seismic event.

- DIRS 103711-Davis, Strenge, and Mishima (1998, all) evaluated the postulated aircraft crash and subsequent fire at a storage facility. The analysis showed that falling aircraft components produced by such an event would not penetrate the storage facility and that a subsequent fire would not result in a facility failure. This conclusion is consistent with representative analyses performed in support of Nuclear Regulatory Commission license applications for above-grade dry storage (DIRS 103449-PGE 1996, all; DIRS 103177-CP&L 1989, all).

  DIRS 103711-Davis, Strenge, and Mishima (1998, all) evaluated aircraft crashes with a velocity of 550 kilometers per hour (340 miles per hour) based on the DOE aircraft crash standard (DIRS 101810-DOE 1996, p. C-7). In a scenario where aircraft velocities could be higher, there would be an increased potential that the intact storage facility could be subject to failure, resulting in a release of radiological materials. DOE has not performed a more detailed analysis of these licensed facilities because the Nuclear Regulatory Commission has a comprehensive program underway to evaluate such events at their licensed facilities, including commercial spent fuel storage facilities. The Commission would be expected to take whatever action is necessary to provide adequate protection to the public from such events.

- For the seismic event, major damage would be unlikely because storage facilities would be designed to withstand severe earthquakes. Even if such an event caused damage, immediate release of radioactive particulates would be unlikely because analyses have identified no mechanism that would cause fuel pellet damage sufficient to create respirable airborne particles (DIRS 103449-PGE 1996, all; DIRS 103177-CP&L 1989, all). Therefore, the source term would be limited to gaseous fission products, carbon-14, and a very small amount of preexisting fuel-pellet dust. Subsequent repairs to damaged facilities or concrete storage modules would preclude the long-term release of radionuclides.

Criticality events are not plausible for Scenario 1 because water, which is required for criticality, could not enter the dry storage canister. The water would have to penetrate several independent barriers, all of which would be maintained and replaced as necessary under Scenario 1. Therefore, DOE determined that potential accident consequences would be bounded by a severe seismic event (see Appendix K, Section K.2.5). DOE analyzed this event and concluded that such an accident scenario would not result in radiological impacts to members of the public in the immediate vicinity of the storage facility. In addition, there would be limited quantities of nonradioactive hazardous or toxic substances stored at the facilities. Therefore, nonradiological accident impacts would be limited to those from industrial hazards and traffic, as discussed in Sections 7.2.1.7.2 and 7.2.1.14, respectively.

7.2.1.9 Noise

During routine operations, noise levels would not affect workers, the public near the facility, or the environment. Most of the storage facilities would have passive cooling, although a few could have active cooling with fans and blowers. Because the storage facilities would be away from population centers or homes, the noise of blowers, if used, would not affect the nearby public. The noise would not be loud enough to produce adverse impacts on the facility workers' hearing.

The analysis assumed for Scenario 1 that the storage facilities would require complete replacement every 100 years. During construction, noise levels due to construction traffic and activities would exceed ambient noise levels. To protect personnel, Occupational Safety and Health Administration standards would be followed (29 CFR 1910.95). The noise could cause wildlife to leave the immediate vicinity of the construction activities, but would not be loud enough to affect individual animals permanently. Adverse impacts to wildlife would be temporary.

7.2.1.10 Aesthetics

Impacts from the storage facilities to aesthetic or scenic resources would be low. There would be two adjacent locations at each site on land that would already be disturbed. Every 100 years, a new facility would be constructed on the idle site, and the storage containers transferred. The old facility would be demolished and the site would remain idle for the next 100 years. Adverse impacts could occur during construction and demolition activities, but these impacts would be short-term and temporary.

7.2.1.11 Utilities, Energy, and Materials

As mentioned above, spent nuclear fuel and high-level radioactive waste storage facilities would have passive cooling, although a few could have active cooling with fans and blowers. Electricity would be required for these cooling systems and to light the storage facilities, but DOE anticipates that the amount of electricity would be small in comparison to the amount available. Fuel and materials would be needed to maintain and repair the facilities and to construct and demolish facilities every 100 years, but DOE expects impacts to these resources to represent a small fraction of the resources available to each of the 77 sites. Therefore, the No-Action Alternative would not produce adverse impacts on these resources during operation and construction activities.

7.2.1.12 Waste Management

Construction of new facilities and demolition of old facilities every 100 years (and the one-time refurbishment of existing facilities after the first 50 years) would generate construction debris and sanitary and industrial solid waste. In addition, routine repairs and maintenance to the facilities and storage containers, routine radiological surveys, and overpacking of failed containers would generate sanitary and industrial solid and low-level radioactive wastes. Because there would not be a dedicated workforce at the storage facilities, only small amounts of sanitary wastes would be generated except during construction periods. The greatest amount of waste would be generated by the demolition of facilities at the 72 commercial and 5 DOE storage sites every 100 years. The demolition of facilities once every 100 years at all the sites would generate, on average, an estimated 770,000 cubic meters (1 million cubic yards) of nonhazardous demolition debris, recyclable steel, and potentially a small amount of low-level waste if a dry storage canister were to fail while in storage (DIRS 104596-Orthen 1999, Table 7). The debris and wastes would be disposed of at commercial or DOE disposal facilities across the Nation. The impacts to available capacity would be spread nationwide, thus minimizing impacts to any one disposal facility. The capacities of the disposal facilities would accommodate the wastes generated at the storage facilities.

7.2.1.13 Environmental Justice

Potential impacts of continued storage with institutional control would be minimal for all populations living near the storage facilities. Because adverse impacts would be unlikely for any population, effects on minority or low-income populations would be unlikely to be disproportionately high and adverse.

Storage facilities would require small areas and would be on lands already owned by commercial utilities or DOE. Therefore, continued storage at these sites would be unlikely to introduce environmental justice concerns. If the United States determines that it will use continued storage at existing sites for the long-term disposition of spent nuclear fuel and high-level radioactive waste, site-specific analyses of storage facilities would be required to determine if environmental justice issues could result. The Nuclear Regulatory Commission has established this approach (DIRS 101899-NRC 1996, p. 9-16).

7.2.1.14 Traffic and Transportation

DOE analyzed short-term impacts (traffic fatalities) that could result from commuting to and from storage facilities for a single 100-year cycle. The amount of travel was determined from estimates of personnel needed to construct the storage facilities, load and reload the canisters into the storage modules, and conduct routine surveillance and repairs (DIRS 104596-Orthen 1999, all). Because the workforce at each storage facility would be small, opportunities for carpooling would be limited. Therefore, the analysis assumed each worker would commute individually.

An estimated 700 workers (see Section 7.2.1.7.3) would commute to and from work approximately 18 million times during the first 100 years. The analysis assumed an average one-way commute of 19 kilometers (12 miles) based on personal travel reported in the Nationwide Personal Transportation Survey by the Oak Ridge National Laboratory (DIRS 102064-FHWA 1999, p. 9). The analysis also used national data to estimate fatalities [in 1994, 1 fatality per 100 million kilometers (about 62 million miles) traveled by automobile (DIRS 148081-BTS 1999, p. 4)] over a single 100-year period. Based on the expected workforce, estimated number of trips, estimated average distance, and fatality data, approximately 7 traffic fatalities would occur in the workforce at the 77 sites in 100 years (or an average of less than 1 fatality every 10 years) (DIRS 104596-Orthen 1999, Table 6).

In addition, the analysis estimated the long-term traffic fatalities for the remaining 9,900-year analysis period. Using the estimated number of full-time equivalent work years of 7.4 million, about 730 traffic fatalities would be likely during the 9,900-year analysis period at the 77 sites (or, on average, less than 1 fatality every 10 years).

The analysis also estimated traffic fatalities and latent cancer fatalities from trucks transporting construction materials to and demolition debris from the 77 sites assuming an 80-kilometer (50-mile) roundtrip distance. For the 9,900-year period, during the construction of replacement facilities, construction vehicles would travel about 1.2 billion kilometers (750 million miles), resulting in approximately 17 prompt traffic fatalities, or less than 1 fatality every 600 years (DIRS 103455-Saricks and Tompkins 1999, Table 4, pp. 34 and 35) and about 0.1 latent fatality from vehicle exhaust emissions.

7.2.1.15 Sabotage

Above-ground storage of spent nuclear fuel and high-level radioactive waste for 10,000 years would entail a continued risk of intruder access at each of the 77 sites. Sabotage could result in a release of radionuclides to the environment around the facility. Under Scenario 1, the analysis assumed that safeguards and security measures currently in place would remain in effect during the 10,000-year analysis period, thereby reducing the risk of sabotage.

As Nuclear Regulatory Commission licensees, the individual sites would be required to comply with Commission regulations and maintain the highest level of security as determined by the Commission, and any results from the reexamination of existing physical security and safeguard systems following the terrorist attack of September 11, 2001.

Because it is not possible to predict whether sabotage events would occur, and if they did, the nature of such events, DOE examined various accident scenarios in this Final EIS, which provide an approximation of the consequences that could occur.

7.2.2 NO-ACTION SCENARIO 2

DOE and commercial utilities intend to maintain control of the nuclear storage facilities as long as necessary to ensure public health and safety. However, Scenario 2 assumes no effective institutional control of the storage facilities after approximately the first 100 years to provide a basis for evaluating an upper limit of potential adverse human health impacts to the public from the continued storage of spent nuclear fuel and high-level radioactive waste. After about 100 years, Scenario 2 assumes that there would be no effective institutional control and that the storage facilities would be abandoned. Therefore, there would be no health risks for workers during that period. For the long-term impacts after about 100 years and for as long as 10,000 years, the analysis assumed that the spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate and that radioactive materials would be released to the environment, contaminating the local atmosphere, soil, surface water, and groundwater. Appendix K provides details of facility degradation, radioactive material environmental transport, and human radiological exposure and dose models.

Because Scenario 2 assumes effective institutional control during the first 100 years of the 10,000-year analysis period, the short-term impacts of that first 100 years would be the same as the impacts described for Scenario 1 (see Section 7.2.1). Therefore, this discussion focuses on long-term impacts (after the first approximately 100 years). However, after about 100 years under Scenario 2, when there would no longer be effective institutional control, construction and operation activities would not occur at the storage sites; therefore, socioeconomic and cultural resources would be unlikely to receive adverse impacts. In addition, noise would not emanate from the facilities; utilities, energy, or materials would not be expended; waste would not be generated; and workers would not commute to the sites. Thus, after approximately the first 100 years, No-Action Alternative Scenario 2 would not adversely affect socioeconomic and cultural resources; scenic resources; noise; utilities, energy and materials; waste management; or traffic and transportation. Aesthetic resources would not change until the facilities began to degrade, at which time the aesthetic value of the sites would change.

7.2.2.1 Land Use and Ownership

Without maintenance and periodic replacement, facilities, storage containers, and the spent nuclear fuel and high-level radioactive waste would begin to deteriorate. Eventually radioactive materials would contaminate the land surrounding the storage facilities, possibly rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. The amount of land contaminated would depend on several factors including the climate of the region, the amount of spent nuclear fuel and high-level radioactive waste at the site, and the rate of deterioration. Although the size of the affected area would be impossible to predict accurately for each site, DOE believes it would involve tens to hundreds of acres at each of the 77 sites.

By assuming that there would be no effective institutional control, this scenario also assumes that there would not be an orderly conversion of land use and ownership to other uses or ownership and that all knowledge of the purpose and content of the facilities would be lost. This would increase the likelihood that members of the public would move onto storage facility lands because they would not be aware of the potential radioactive material contamination.

7.2.2.2 Air Quality

As discussed in Appendix K, Section K.2.3, the degraded facilities would provide sufficient protection of the spent nuclear fuel and high-level radioactive waste materials to preclude the release of particulate radioactive materials in sufficient quantities to affect air quality adversely. Small releases of gaseous carbon-14 would be likely in the form of carbon dioxide gas but would not adversely affect ambient air quality.

7.2.2.3 Hydrology

7.2.2.3.1 *Surface Water*

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, contaminants would enter surface waters from stormwater runoff from the failed facilities and storage containers and exposed radioactive materials. The introduction of contaminants would continue over a long period until the depletion of the source materials. During this release period, contaminant releases to surface waters could be sufficient to produce adverse impacts to human health. Section 7.2.2.5.3 discusses impacts to the public using this water for drinking.

7.2.2.3.2 *Groundwater*

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, contaminants would enter the groundwater. Once contaminated, aquifers beneath the degraded storage facilities would remain contaminated for the period required for the depletion of the spent nuclear fuel and high-level radioactive waste materials and the migration of the contaminants from the groundwater system. Contaminant concentrations in the groundwater could be sufficient to produce adverse impacts to human health. Section 7.2.2.5.3 discusses impacts to the public using groundwater for drinking, bathing, and irrigation.

7.2.2.4 Biological Resources and Soils

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, the potential for individual animals to be exposed to radiation at the storage sites would increase. In addition, animals could drink contaminated surface water. Direct radiation from the exposed spent nuclear fuel and high-level radioactive waste storage canisters and concentrations of contaminants in surface waters could produce adverse impacts to animals. While the contaminant exposure could have negative effects, including death, on individual animals, adverse effects to entire populations would be unlikely because the lethal area surrounding the degraded facilities would be limited to a few hundred acres.

Soils at the storage facilities could be contaminated by radioactive materials leaching from the spent nuclear fuel and high-level radioactive waste material. Soils downslope of the facilities could be contaminated by surface-water runoff. Crops grown on these soils would take up some of the contamination, thus making the contaminated soils a pathway for human exposure. Section 7.2.2.5.3 discusses impacts to members of the public from ingesting food grown in or livestock fed from contaminated soils.

7.2.2.5 Occupational and Public Health and Safety

7.2.2.5.1 *Nonradiation Exposures*

Analyses performed for the repository (see Chapter 5, Section 5.6) indicate that concentrations of chemically toxic materials (that is, molybdenum, nickel, vanadium, and chromium) from degraded spent nuclear fuel and high-level radioactive waste packages in the groundwater would be extremely low. Therefore, because of the relatively lower abundance of these materials contained in the stainless steel storage canisters and relatively greater abundance of water and the greater precipitation at the storage locations than at the repository, concentrations of the materials in the groundwater and surface water at the storage sites would likely be much lower than those estimated for the repository. The Department did not attempt to quantify adverse health impacts from chemical toxicity of the waste forms (principally uranium dioxide and *borosilicate glass*) that could occur within the exposed population under Scenario 2. This decision is consistent with the Department's position that care should be taken not to overestimate impacts from the No-Action Alternative.

7.2.2.5.2 *Industrial Hazards*

For about the first 100 years, industrial hazards would be the same as for the first 100 years under Scenario 1 (see Section 7.2.1.7.2). After about 100 years, Scenario 2 assumes there would be no effective institutional control and that the storage facilities would be abandoned and, therefore, there would be no industrial safety impacts.

7.2.2.5.3 *Radiation Exposures*

To simplify the analysis, DOE divided the United States into five regions (Figure 7-7). Regional radiological impacts were estimated by assuming all spent nuclear fuel and high-level radioactive waste in a particular region was stored at a single hypothetical site in that region. Appendix K, Section K.2.1.6, provides details of the methods and assumptions used in the regional analysis.

Radiological impacts to occupational workers and the offsite public from initial construction, routine maintenance and operations, and refurbishment after the first 50 years would be the same as those for the same period under Scenario 1 (see Section 7.2.1.7.3 and Table 7-6).

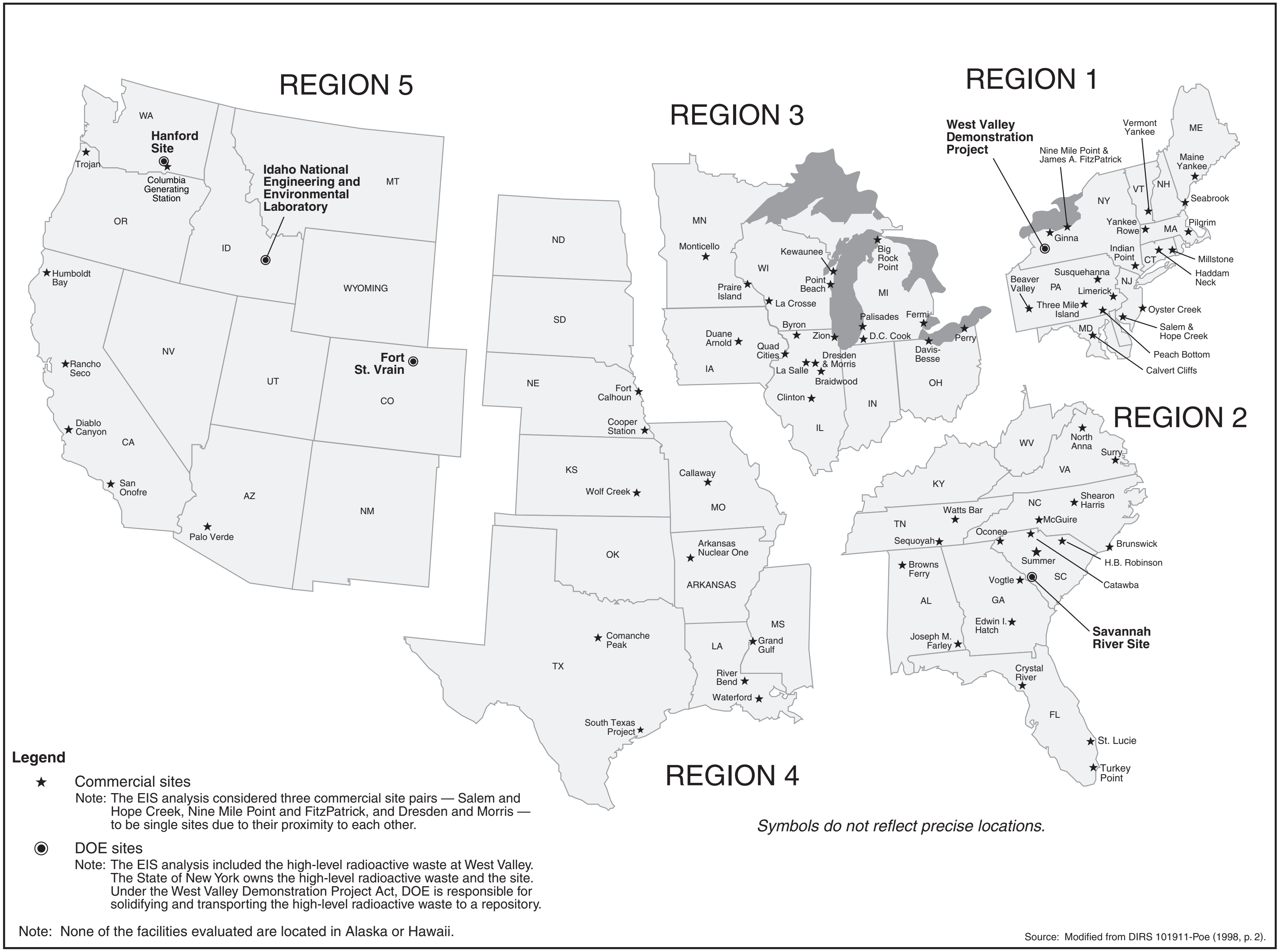

Figure 7-7. Commercial and DOE sites in each No-Action Alternative analysis region.

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For Scenario 2 DOE assumed that after approximately the first 100 years there would be no institutional control and that deterioration of the facilities would occur over time. Based on regional climate and degradation models (see Appendix K), the spent nuclear fuel and high-level radioactive waste storage facilities and dry storage containers would corrode and fail over time, exposing radioactive material to the environment (wind and rain). Once exposed to the environment, the spent nuclear fuel and high-level radioactive waste storage packages and facilities would begin releasing small quantities of radioactive material to the atmosphere (gaseous carbon-14), soil, surface water, and groundwater, resulting in exposures to the public. These released materials could produce chronic exposures to the public, which could result in adverse health impacts. Figure 7-8 shows the conceptual timeline for activities and degradation processes at the storage facilities for Scenario 2.

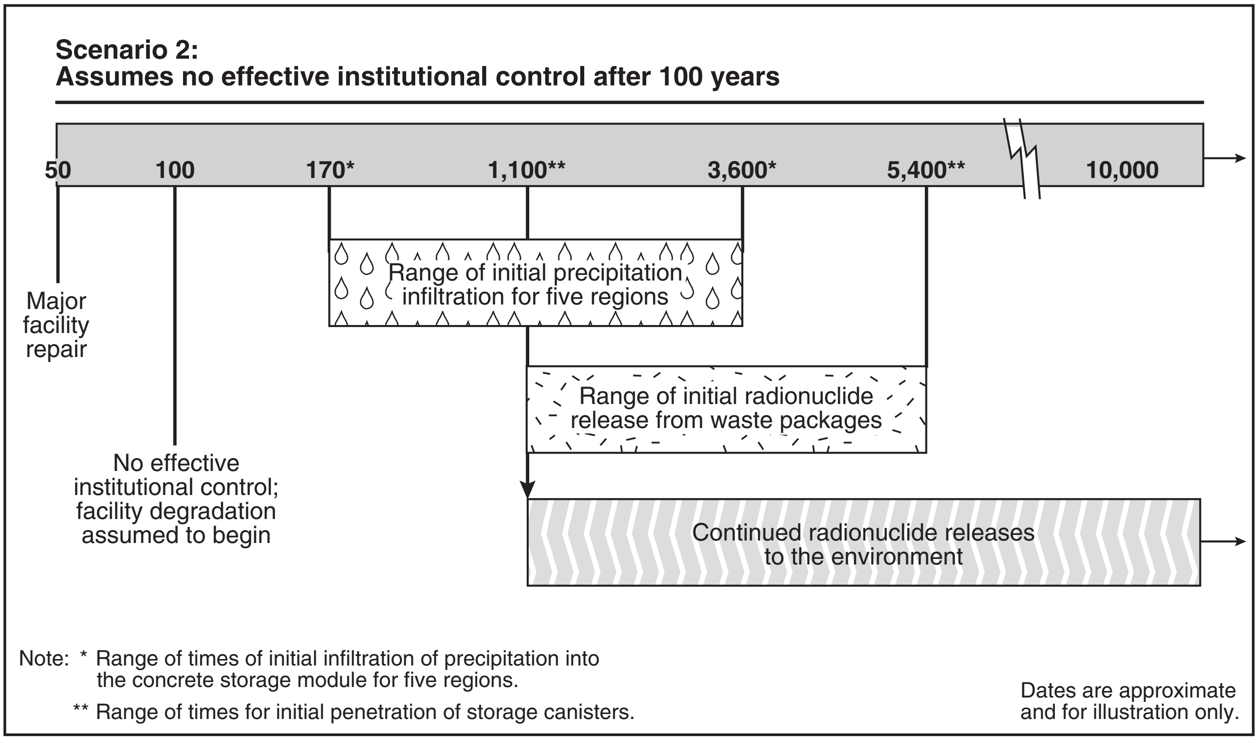

Figure 7-8. Conceptual timeline for activities and degradation processes for No-Action Scenario 2.

Appendix K describes the methods used to estimate impacts to human health from long-term environmental releases and human intrusion. The radiological impacts on human health include internal exposure from intake of radioactive materials in surface water and groundwater.

Table 7-7 lists the estimated radiological drinking water impacts during the 9,900 years under Scenario 2 with the assumption of no effective institutional control. The impacts listed in Table 7-7 are from drinking water only and would result from consuming water from the major waterways contaminated with radioactive materials by groundwater discharge and surface-water runoff from degraded spent nuclear fuel and high-level radioactive waste storage facilities. DOE evaluated

Table 7-7. Estimated long-term collective drinking water radiological impacts to the public from long-term storage of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites – Scenario 2.

9,900-year population dose[a] (person-rem)	9,900-year LCFs[b]	Years to peak impact[c]
6,600,000	3,300	3,400

a. Estimated total population (collective) dose from drinking water pathway (DIRS 101935-Toblin 1999, p. 4).
b. LCFs = latent cancer fatalities; estimated for the exposed population group based on an assumed risk of 0.0005 latent cancer fatality per person-rem of collective dose (DIRS 101857-NCRP 1993, p. 112).
c. Years after period of institutional control when the maximum doses would occur.

other potential impacts to populations (for example, exposure to people living on the contaminated floodplains) and to individuals (for example, consumption of contaminated food) and determined that certain individuals could receive doses as much as three times higher than for drinking water alone but that doses to populations from contaminated floodplains would represent less than 10 percent of the impacts listed in Table 7-7. DOE did not include these impacts in Table 7-7 because the dose to an individual would depend largely on highly variable subsistence habits and because DOE did not want to overestimate the impacts from Scenario 2.

Figure 7-9 shows the locations of the commercial and DOE sites in the United States and the more than 20 major waterways potentially affected. At present, municipal water systems that serve 31 million people have intakes along the potentially affected portions of these waterways. The analysis assumed these populations would remain constant over the entire analysis period (9,900 years). Over the 9,900-year analysis period, about 140 70-year lifetime periods would be affected. Because the analysis estimated that releases would not occur during the first 1,000 years for most regions, the estimated potentially exposed population would be about 3.9 billion.

Table 7-7 indicates that over 9,900 years, a collective drinking water dose of 6.6 million person-rem could result in an additional 3,300 latent cancer fatalities in the total potentially exposed population of 3.9 billion. This latent cancer fatality rate would affect an average of about 24 people per 70-year lifetime, or about 1 latent cancer fatality at each of the 77 sites every 200 years. These radiation-induced latent cancer fatalities would be in addition to about 900 million fatal cancers (using the lifetime fatal cancer risk of 24 percent [DIRS 153066-Murphy 2000, p. 5]) that would be likely from all other causes in the exposed population, an incremental increase over the natural incidence of fatal cancer of about 0.0004 percent.

Figure 7-10 shows the estimated latent cancer fatalities for approximately 140 70-year periods during the 9,900-year period of analysis. The five peaks shown in Figure 7-10 generally result from contributions of each of the five regions (see Appendix K, Figure K-8). The major peak, which would occur about 3,400 years after effective institutional control ended (in 2100), would be due to radionuclide releases at the sites that drain to the Mississippi River and the relatively large populations along the Mississippi and its tributaries.

In addition to the 3,300 potential cancer fatalities under Scenario 2, more than 20 major waterways of the United States that currently supply domestic water to about 31 million people (for example, the Great Lakes; the Mississippi, Ohio, and Columbia Rivers; and many smaller rivers along the Eastern Seaboard) could be contaminated with radioactive material. Under this scenario, the shorelines could be contaminated with long-lived radioactive materials (for example, plutonium, uranium, and americium), resulting in exposures to individuals who came in contact with the sediments and, potentially, an increase in latent cancer fatalities. Because individuals would not be in constant contact with the sediments, these impacts represent a small fraction of the impacts estimated for the drinking water pathways listed in Table 7-7.

For purposes of comparison with impacts associated with the Proposed Action, DOE evaluated potential radiological impacts for a maximally exposed individual by constructing hypothetical exposure scenarios for individuals living near the degraded facilities. The exposure scenarios maximized external and internal exposure over each 70-year lifetime period in the 9,900-year period of analysis. The following paragraphs describe the results of these evaluations.

For Scenario 2, localized impacts to individuals from degraded facilities at the 77 sites could be severe. DOE estimated that within a few hundred years at the several sites where early concrete failure was predicted, hypothetical individuals living close to the storage facilities would receive lethal doses of

Figure 7-9. Major waterways near commercial and DOE sites.

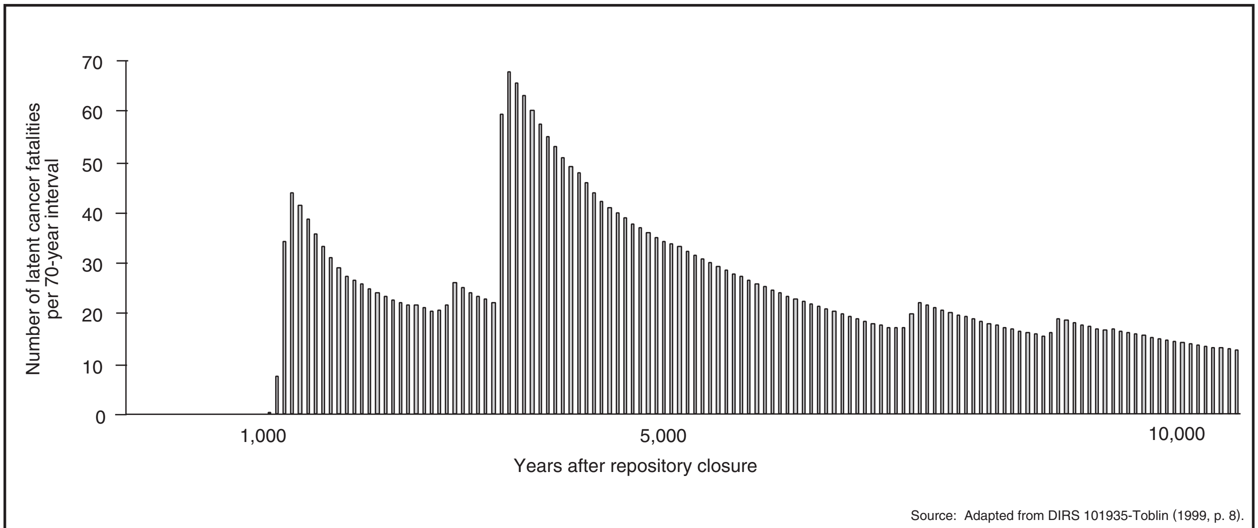

Figure 7-10. Potential latent cancer fatalities throughout the United States from No-Action Scenario 2.

external radiation [800 millirem per hour at a distance of 10 meters (33 feet)] from the exposed dry storage containers (see Appendix K, Section K.2.4.2).

To evaluate impacts from ingestion of radioactive materials, the analysis assumed that individuals would live near the degraded storage facilities and would consume contaminated groundwater and food from gardens irrigated with groundwater withdrawn from the contaminated aquifer directly below their locations. DOE estimated that within 6,000 years from now a hypothetical individual living within several hundred meters of a degraded facility could receive an internal committed effective dose equivalent to several thousand rem per year from ingestion of plutonium-239 and -240 (see Appendix F for further information on committed dose equivalent). Using the National Council on Radiation Protection and Measurements risk factors (DIRS 101857-NCRP 1993, p. 112), ingestion of plutonium at this rate could increase the individual's lifetime risk of contracting a fatal cancer after only a few years of exposure.

In addition, DOE estimated impacts for a hypothetical individual living 5 kilometers (3 miles) from the degraded facility on the downgradient of the contaminated aquifer. Although this individual would be too distant from the facility to receive any appreciable external radiation dose, the internal dose from the consumption of contaminated groundwater and contaminated crops could still be as high as 30 rem per year from ingestion of plutonium-239 and -240. Ingestion of plutonium at this rate could increase the individual's risk of contracting a fatal cancer after several decades of exposure. Appendix K provides details on the methods DOE used to evaluate localized impacts.

Uncertainty

This section contains estimates of the radiological impacts of No-Action Scenario 2, which assumes continued above-ground storage of spent nuclear fuel and high-level radioactive waste at sites across the United States. Associated with the impact estimates are uncertainties typical of predictions of the outcome of complex physical and biological phenomena and of the future state of society and societal institutions over long periods. DOE recognized this fact from the start of the analysis; however, the predictions will be valuable in the decisionmaking process because they provide insight based on the best information and scientific judgments available.
This analysis considered five aspects of uncertainty:

- Uncertainties about the nature of changes in society and its institutions and values, in the physical environment, and of technology as technology progresses

- Uncertainties associated with future human activities and lifestyles
- Uncertainties associated with the mathematical representation of the physical processes and with the data in the computer models
- Uncertainties associated with the mathematical representation of the biological processes involving the uptake and metabolism of radionuclides and the data in the computer models
- Uncertainties associated with accident scenario analysis

For the No-Action Scenario 2 analysis DOE has not attempted to quantify the variability of estimated impacts related to possible changes in climate, societal values, technology, or future lifestyles. To simplify the analysis, DOE did not attempt to quantify these uncertainties even though uncertainties with these changes could undoubtedly affect the total consequences reported in Table 7-7 by several orders of magnitude.

DOE attempted to quantify a range of uncertainties associated with mathematical models and input data, and estimated the effect these uncertainties could have on collective human health impacts. By summing the uncertainties (see Appendix K, Sections K.4.1, K.4.2, and K.4.3 for details), DOE estimated that total collective impacts over 10,000 years could have been underestimated by as much as 3 or 4 orders of magnitude. However, because there are large uncertainties in the models used to quantify the relationship between low doses (less than 10 rem) and the accompanying health impacts (see Appendix F, Section F.1.1.5), especially under conditions in which the majority of the population would be exposed at a very low dose rate, DOE believes the actual collective impact could be small.

On the other hand, impacts to individuals (human intruders) who could move to the storage sites and live close to the degraded facilities could be severe. During the early period (200 to 400 years after the assumed loss of institutional control), acute exposures to external radiation from the spent nuclear fuel and high-level radioactive waste material could result in prompt fatalities. In addition, after a few thousand years onsite shallow aquifers could be contaminated to such a degree that consumption of water from those aquifers could result in severe adverse health effects, including premature death. Uncertainties about these localized impacts are related primarily to the inability to predict accurately how many individuals could be affected at each of the 77 sites over the 10,000-year analysis period. In addition, the uncertainties associated with localized impacts would exist for potential consequences resulting from unusual events, both manmade and natural.

Therefore, uncertainties resulting from surface storage where containers are more readily affected by natural phenomena and human behavior (see Appendix K, Table K-14) that cannot be predicted, process model uncertainties, and dose-effect relationships, taken together, could produce the results listed in Table 7-7, overestimating or underestimating the actual impacts by as much as several orders of magnitude.

7.2.2.6 Atmospheric Radiological Consequences

As discussed in Appendix K, Section K.2.3, the analysis assumed that the configuration of the degraded storage facilities would cause debris to cover the radioactive material, which would remain inside the dry storage canisters. While the dry storage canisters could fail sufficiently to permit water to enter, they would probably retain their structural characteristics, thereby minimizing the dispersion of particulate radioactive material to the atmosphere (DIRS 147905-Mishima 1998, all). However, the radionuclides carbon-14 and iodine-129 would have a potential for gas transport. Although iodine-129 can exist in a gas phase, DOE expects it would dissolve in the precipitation and migrate in surface water and groundwater. DOE also expects the consequences from a release of carbon-14 to be very small based on the low failure rate of zirconium-clad spent nuclear fuel (see Appendix K, Section K.2.1.4.1 for details) and large atmospheric dilution.

7.2.2.7 Accidents

For Scenario 2, the analysis examined the impacts of an accident scenario that could occur during the above-ground storage of spent nuclear fuel and high-level radioactive waste and concluded that the most severe accident scenarios would be an airplane crash into a concrete storage module. The frequency of such an event was estimated to be 0.0000032 (3 in 1 million) crashes per year.

In Scenario 2, the concrete storage modules would deteriorate with time. DOE concluded that an airplane crash into a degraded concrete storage module would dominate the consequences from external initiating events (see Appendix K, Section K.3.2.1). The analysis evaluated the potential for criticality accidents and concluded that an event severe enough to produce large consequences would be extremely unlikely, and that the consequences would be bounded by the airplane crash consequences. Table 7-8 lists the consequences of an airplane crash on a degraded concrete storage module.

Table 7-8. Estimated consequences of an aircraft crash on a degraded spent nuclear fuel concrete storage module.[a]

Factor	High population site[b]	Low population site[c]
Frequency (per year)	3.2×10^{-6}	3.2×10^{-6}
Collective population dose (person-rem)	26,000	6,100
Latent cancer fatalities	13	3

a. Source: DIRS 103711-Davis, Strenge, and Mishima (1998, p. 11).
b. Within 80 kilometers (50 miles) of site, an average of 330 persons per square mile.
c. Within 80 kilometers of site, an average of 77 persons per square mile.

7.2.2.8 Environmental Justice

Deteriorating facilities, storage containers and packaging, and spent nuclear fuel and high-level radioactive waste could produce adverse effects to the nearby public. Any nearby minority or low-income communities could experience disproportionately high and adverse human health impacts. In addition, financial considerations could make it more difficult for members of any affected minority or low-income populations to obtain uncontaminated resources or to move away from contaminated soils and water. Because subsistence patterns for low-income and minority populations could vary from those of persons not in these groups, any affected low-income and minority populations could be exposed to greater than average doses. The result of differing potentials for exposure could be disproportionately high and adverse impacts to minority or low-income populations.

If the United States determines that it will use continued storage at existing sites for the long-term disposition of spent nuclear fuel and high-level radioactive waste, site-specific analyses of storage facilities would be required to identify if environmental justice issues could result. The Nuclear Regulatory Commission established this approach (DIRS 101899-NRC 1996, p. 9-16). With the assumption of no effective institutional control after about 100 years, potential environmental justice issues identified under Scenario 2 probably would be more severe than those identified under Scenario 1 (see Section 7.2.1.13).

7.2.2.9 Sabotage

For Scenario 2, the storage of spent nuclear fuel and high-level radioactive waste for 10,000 years without institutional control would entail a greater risk of intruder access at the 77 sites than exists under current conditions. Due to the lack of institutional control and degraded facilities, sabotage could result in a release of radionuclides to the environment around the facility. The analysis assumed that safeguards and security measures would not be maintained after approximately the first 100 years. For the remaining

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9,900 years of the analysis period, the cumulative risk of intruder attempts would increase. As the *storage containers* degraded, they would become more vulnerable to failure. Any amount of material released from its storage container could contaminate areas with radioactivity. Therefore, the risks of sabotage would increase substantially under this scenario in comparison to Scenario 1.

7.3 Cumulative Impacts for the No-Action Alternative

DOE evaluated the disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the Proposed Action analysis. To provide a direct comparison of impacts with the Proposed Action, the No-Action analysis in Sections 7.1 and 7.2 evaluated the impacts of the continued storage of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites across the United States. DOE chose the volume of 70,000 MTHM for analysis because the NWPA prohibits the Nuclear Regulatory Commission from approving the emplacement of more than 70,000 MTHM in a first repository until a second repository is in operation. This section describes the results of the analysis of the cumulative impacts of the continued storage at the 77 existing sites of all spent nuclear fuel and high-level radioactive waste (called Inventory Module 1) (Table 7-9). Chapter 8 discusses the cumulative impacts of disposing of radioactive waste at the Yucca Mountain Repository in excess of the Proposed Action repository.

Table 7-9. Inventories for Proposed Action and Module 1.[a]

Material	Proposed Action	Module 1
DOE spent nuclear fuel	2,333 MTHM	2,500 MTHM
Commercial spent nuclear fuel[b]	63,000 MTHM	105,000 MTHM
High-level radioactive waste[b]	8,315 canisters	22,280 canisters

a. Source: Appendix A, Section A.1.1.4.1.

b. Surplus plutonium would be included in the inventory in the form of mixed-oxide fuel (treated as commercial spent nuclear fuel) or immobilized plutonium (high-level radioactive waste).

A cumulative impact is defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). Cumulative impact assessment is based on both the geographic (spatial) and time (temporal) considerations of past, present, and reasonably foreseeable actions. Geographic boundaries can vary by discipline depending on the time an effect remains in the environment, the extent to which the effect can migrate, and the magnitude of the potential impact. The proximity of other actions to the spent nuclear fuel storage sites is not the only decisive factor for determining the inclusion of an action in the assessment of cumulative impacts. Another, and for this analysis more important, factor is if the other actions would have some influence on the resources in the same time and space affected by continued storage.

The cumulative impacts of past actions have either passed through the environment or are part of existing baseline conditions. For example, the construction impacts of spent nuclear fuel storage facilities will have passed through the environment before the potential impacts associated with continued storage and refurbishment would first be seen in 2002.

DOE based its estimates of the potential impacts from continued storage of commercial spent nuclear fuel on a representative site. The results of the analysis described in the previous section are consistent with the Nuclear Regulatory Commission's findings in its *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (DIRS 101899-NRC 1996, pp. 6-85 and 6-86). The NRC stated:

> *The Commission's regulatory requirements and the experience with on-site storage of spent fuel in fuel pools and dry storage has been reviewed. Within the context of a license renewal review and*

> *determination, the Commission finds that there is ample basis to conclude that continued storage of existing spent fuel and storage of spent fuel generated during the license renewal period can be accomplished safely and without significant environmental impacts. Radiological impacts will be well within regulatory limits; thus radiological impacts of on-site storage meet the standard for a conclusion of small impact. The nonradiological environmental impacts have been shown to be not significant; thus they are classified as small. The overall conclusion for on-site storage of spent fuel during the term of a renewed license is that the environmental impacts will be small for each plant. The need for the consideration of mitigation alternatives within the context of renewal of a power reactor license has been considered, and the Commission concludes that its regulatory requirements already in place provide adequate mitigation incentives for on-site storage of spent fuel.*

Although this finding is applicable only to the continued storage of existing spent nuclear fuel and spent nuclear fuel generated during the 20-year license renewal period for the nuclear powerplant, DOE has concluded that potential environmental and radiological impacts for the storage facility would remain small for much longer periods. Environmental impacts would remain small because no additional fuel would be generated beyond the operation of the nuclear powerplant (plants are assumed to be closed after the first 20-year license renewal period), and radiological impacts would remain within regulatory limits specified in the storage facility license (10 CFR Part 72).

In general, the analysis of cumulative effects can exclude future actions if:

- The action is outside the geographic boundaries or timeframe established for the cumulative effects analysis.
- The action will not affect resources that are the subject of the cumulative effects analysis.
- Including the action would be arbitrary.

Because the estimated impacts would be small, DOE has not attempted to speculate on other arbitrary generic actions that could influence the cumulative impacts generated at a given site. However, the total incremental impact nationally of selected parameters is presented in the preceding section. In addition, the potential impacts at each site do not overlap because the storage sites are located throughout the United States. Therefore, cumulative impacts among the sites on resources would be unlikely.

For the 5 DOE sites, there is a long legacy of EISs and annual monitoring reports. The incremental impacts associated with continued storage of spent nuclear fuel can be added to the results reported in these documents to obtain an estimate of total impacts. For the 72 diverse commercial sites, information on other present and reasonably foreseeable actions varies in terms of data availability and quality. As a consequence, a comparison of cumulative assessments would be problematic, even if the impacts were not as small as the analyses indicate.

The cumulative analysis in this section includes the total projected inventory of commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste (referred to as Module 1) that could come to the repository. Table 7-9 lists the inventories for the Proposed Action analysis and the Module 1 cumulative analysis.

For consistency with the cumulative impact analysis in Chapter 8, the No-Action analysis considered the same spectrum of environmental impacts as the Proposed Action. However, because of the DOE commitment to manage spent nuclear fuel and high-level radioactive waste safely, the Department decided to focus the No-Action cumulative analysis on the short- and long-term health and safety of workers and members of the public. Therefore, quantitative estimates of the cumulative impacts in this section include occupational and public health and safety, waste management, and traffic and transportation. The qualitative discussions of other disciplines are included for completeness.

DOE recognizes that approximately 2,100 cubic meters (74,000 cubic feet) of commercial low-level radioactive waste will exceed Nuclear Regulatory Commission Class C limits (listed in 10 CFR 61.55, Tables 1 and 2 for long and short half-life radionuclides, respectively). This type of waste, called *Greater-Than-Class-C low-level waste*, is generally not suitable for near-surface disposal (see Appendix A, Section A.2.5, for a detailed description). Similarly, DOE low-level radioactive waste that exceeds the Nuclear Regulatory Commission Class C limits (referred to as *Special-Performance-Assessment-Required waste*) will amount to about 4,000 cubic meters (142,000 cubic feet) (see Appendix A, Section A.2.6, for a detailed description). Together these waste types, added to the Module 1 inventory, comprise the Module 2 inventory.

The NWPA does not specifically consider Greater-Than-Class-C or Special-Performance-Assessment-Required wastes. Therefore, DOE has not included either waste type in the Proposed Action inventory for the consideration of potential impacts that could occur from the disposal of spent nuclear fuel and high-level radioactive wastes in a geologic repository at Yucca Mountain. The disposal of these wastes at Yucca Mountain, however, is part of the cumulative impact analysis (see Chapter 8) because the impacts of that disposal are reasonably foreseeable as the results of future actions.

Further, DOE has not included Module 2 in its consideration of potential impacts under the No-Action Alternative. DOE does not have enough information about Module 2 wastes at present to be able to perform a meaningful analysis with respect to the No-Action Alternative. As discussed in Appendix A, Section A.2.5, Greater-Than-Class-C waste could include, for example, certain commercial nuclear powerplant operating and decommissioning wastes and sealed radioisotope sources. DOE Special-Performance-Assessment-Required waste could include certain production reactor operating wastes, production and research reactor decommissioning wastes, sealed radioisotope sources, and isotope production-related wastes (see Appendix A, Section A.2.6). As just one example of the confounding potential sources of these types of wastes, in 1993 DOE estimated that 2,552 Greater-Than-Class-C low-level waste fixed-gauge and X-ray fluorescence sealed sources (general licensees) and 7,582 sealed sources (for example, calibration, medical, well logging sources) were used and stored by private industry at hundreds of locations in the United States (DIRS 101798-DOE 1994, all).

As this example illustrates, a meaningful analysis would need to consider the sites, or combination of sites, at which these waste types are currently in use and storage. The analytic approach used to construct the regional representative sites for which the continued storage of spent nuclear fuel and high-level radioactive waste was evaluated would not apply to the hundreds of additional locations associated with Greater-Than-Class-C and Special-Performance-Assessment-Required wastes.

For the spent nuclear fuel and high-level radioactive waste analysis in this EIS (see Appendix K, Section K.2.1), DOE collected information from published sources for each of the 77 sites where spent nuclear fuel and high-level radioactive waste is located and, to simplify the analysis, divided the country into five regions. The Department then configured a single hypothetical site in each region (see Appendix K, Section K.2.1.6), which enabled it to estimate the potential release rate of the radionuclide inventory from the spent nuclear fuel and high-level radioactive waste, based on forecast interactions of the environment (rainfall, freeze-thaw cycle) with the engineered barrier (concrete storage modules).

Environmental information at the hundreds of sites in which Greater-Than-Class-C and Special-Performance-Assessment-Required wastes are in use and storage is not readily available and DOE could not obtain it without an exorbitant commitment of resources. Relevant environmental evaluations such as those prepared by the Nuclear Regulatory Commission for operating commercial nuclear powerplants or spent nuclear fuel storage installations are not available for most of the locations at which these waste types are in use or storage. Further, the manner in which Greater-Than-Class-C and Special-Performance-Assessment-Required low-level wastes are stored varies by waste types, and the great variety of storage methods could not be simplified for analytical purposes without distorting the resulting potential environmental impacts.

Even if such information were gathered and the means of storage could be reduced by the use of simplifying assumptions, the results of the analysis (the impacts) would tend to reinforce the results of the impact analysis performed for the Module 1 inventory. That is, short-term impacts such as those to socioeconomics and land use would not increase appreciably, but health effects probably would increase over the long term because workers and the public would be exposed to these waste types in addition to spent nuclear fuel and high-level radioactive waste at the many locations across the United States.

7.3.1 SHORT-TERM IMPACTS IN THE YUCCA MOUNTAIN VICINITY

Candidate materials would not be transported to the repository. Therefore, impacts from Module 1 would be the same at the Yucca Mountain site as those presented in Section 7.1.

7.3.2 SHORT- AND LONG-TERM IMPACTS AT COMMERCIAL AND DOE SITES

7.3.2.1 Land Use and Ownership

Under Scenario 1 (long-term institutional control), as discussed in Section 7.2.1.1, the land required for storage facilities typically would be a few acres. For the Module 1 inventory, the analysis assumed that the land required would increase, on average, by about 60 percent (the ratio of Proposed Action and Module 1 inventories). This additional land requirement [less than 0.04 square kilometer (10 acres) per site] would represent a small percentage of the land currently available at the sites; therefore, the incremental impacts on land use would be minimal but larger than those for the Proposed Action facilities. These storage facilities would be on land currently owned by DOE or a utility and, therefore, would be unlikely to affect land ownership.

Under Scenario 2 (assumption of no effective institutional control after about 100 years), as discussed in Section 7.2.2.1, without maintenance and periodic replacement, facilities, storage containers, and the spent nuclear fuel and high-level radioactive waste would begin to deteriorate, eventually contaminating the land surrounding the storage facilities and rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. The additional inventories of Module 1 probably would increase the concentrations of radioactive materials in the soils and the size of the affected areas over those expected for the Proposed Action inventory. As with the Proposed Action, these concentrations and areas would be difficult to estimate but even with the additional inventories of Module 1, DOE believes it would involve less than several hundred acres at each of the 77 sites.

In addition, as with the Proposed Action, because Scenario 2 assumes no effective institutional control after approximately 100 years, there would not be an orderly conversion of land use and ownership to other uses or ownership. Therefore, the potential for members of the public to move onto storage facility lands with Module 1 inventories would be unchanged from that expected for the Proposed Action.

7.3.2.2 Air Quality

As discussed in Section 7.2.1.2, under Scenario 1 best management practices and effective monitoring procedures would ensure that contaminant releases to the air would be minimal and would not exceed current regulatory limits (40 CFR Part 61 for hazardous air pollutants emissions and Part 50 for air quality standards). In addition, DOE expects that these controls would be effective with the additional inventories of Module 1. Therefore, air quality under Scenario 1, Module 1 would not be adversely affected during routine operations.

As discussed in Section 7.2.1.2, during the construction of replacement facilities, exhaust from construction vehicles would temporarily increase local concentrations of hydrocarbons, carbon monoxide, and oxides of nitrogen for a few years during each 100 years. DOE expects that these temporary increases in particulate matter resulting from construction activities would persist for slightly longer periods because of the additional facilities required to store the additional inventories of Module 1. However, mitigation measures such as watering unpaved roads would limit the generation of fugitive dust. As with the Proposed Action, after replacement the old site would be seeded, graveled, or paved to reduce air emissions. Therefore, although adverse air quality impacts during construction would be slightly higher for the Module 1 inventory, DOE expects them to be minimal and transient.

The Module 1 air quality impacts under Scenario 2, as discussed in Section 7.2.2.2, would be minimal because even degraded facilities would limit the release of radioactive particulate material to the atmosphere.

7.3.2.3 Hydrology

7.3.2.3.1 *Surface Water*

For Scenario 1, as discussed in Section 7.2.1.3.1, under long-term institutional control, best management practices such as stormwater pollution prevention plans and stormwater holding ponds would ensure that, in the unlikely event of an inadvertent release, contaminants would not reach surface-water systems. These controls and monitoring procedures would be effective for the additional inventories of Module 1. Therefore, as with the Proposed Action inventory, surface-water quality would not be adversely affected by routine operations.

For long-term impacts from Scenario 2, after about 100 years when there is an assumption of no effective institutional control, the Module 1 contaminants could enter surface water via stormwater runoff from degraded facilities in quantities greater than those expected for the Proposed Action. Section 7.3.2.7.3 discusses the incremental impacts to the public expected from these additional surface water contaminants resulting from the Module 1 inventory.

7.3.2.3.2 *Groundwater*

Under Scenario 1, Module 1 groundwater impacts from the storage of 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, and 22,280 canisters of high-level radioactive waste would be minimal because best management practices such as spill prevention and cleanup plans and procedures and effective effluent monitoring procedures would ensure that inadvertent contaminant releases did not reach groundwater.

In addition, although the analysis assumed that the average square footage of storage facilities would increase by about 60 percent for the additional Module 1 inventory, the shallow foundations of these surface structures would not disturb groundwater systems. Some additional DOE storage facilities would be subsurface structures for which construction could require minimal dewatering of the groundwater aquifer. However, the larger square footage of the Module 1 structures would be relatively small (a few acres) in relation to the size of the aquifer, so no adverse impacts would result from dewatering activities.

For long-term impacts from Scenario 2, Module 1 contaminants would be likely to enter the underlying groundwater from degraded facilities in quantities greater than those expected for the Proposed Action. Section 7.3.2.7.3 discusses the incremental impacts to the public from these additional groundwater contaminants resulting from the Module 1 inventory.

7.3.2.4 Biological Resources and Soils

For Scenario 1, as discussed in Section 7.2.1.4, under long-term institutional control, impacts to biological resources or soils from the construction every 100 years and operation of the storage facilities would be minimal for the expanded Module 1 inventory. The facilities necessary to store the expanded Module 1 inventory would be fenced to keep wildlife out and replacement facilities would be constructed on previously disturbed soil. In addition, as with the Proposed Action, spills would be contained and cleaned up immediately, thus minimizing the area of soil affected.

For long-term impacts from Scenario 2, the analysis assumed that the potential for individual animals to be exposed to radiation at the storage sites would increase in proportion to the increased Module 1 inventory in comparison to the Proposed Action inventory (approximately 60 percent). While the increased contaminant exposure could have negative effects, including death, on individual animals, adverse impacts to entire populations would be unlikely because the lethal area surrounding the degraded facilities would be limited to a few hundred acres.

Contamination of soils at the storage facilities by radioactive materials leaching from the spent nuclear fuel and high-level radioactive waste material would be likely to increase in proportion to the increase in Module 1 inventory. Appendix K, Section K.2.4, discusses impacts to members of the public from eating food grown in contaminated soils or livestock fed on such soils.

7.3.2.5 Cultural Resources

For Scenario 1, the analysis assumed that the Module 1 replacement of spent nuclear fuel and high-level radioactive waste storage facilities would increase by about 60 percent over the Proposed Action. However, these additional facilities would generally be on undeveloped land owned by DOE or the commercial utilities in rural areas. As with the Proposed Action, the size of the additional facilities and supporting infrastructure would be small enough that the facility probably would avoid known cultural resources. In addition, if previously unknown archaeological sites, human remains, or funerary objects were uncovered during construction, DOE or the commercial utility would comply with Executive Orders and Federal and state regulations for the protection of cultural resources. Therefore, construction and operations would not affect cultural resources.

For long-term impacts from Scenario 2, construction and operation for about the first 100 years would be as described for Scenario 1. After this time, no construction or operation activities would occur at the generating sites; therefore, cultural resources would not be adversely affected.

7.3.2.6 Socioeconomics

For Scenario 1, the total staff required at 77 sites to monitor, maintain, and replace the Module 1 facilities would increase from about 700 for the Proposed Action inventory of 70,000 MTHM to more than 800 for the Module 1 inventory of 105,000 MTHM (DIRS 104596-Orthen 1999, Table 6). This increase is approximately equivalent to adding no more than two individuals at each of the 77 sites. Therefore, the additional storage requirements of the Module 1 inventory would be unlikely to affect socioeconomic factors such as infrastructure and regional economy.

For long-term impacts from Scenario 2, because there is an assumption of no effective institutional control after about 100 years, there would be no workers for either the Proposed Action or Module 1 inventories. Therefore, the Module 1 socioeconomic impacts would be essentially the same as those for the Proposed Action for the first 100 years, but after that approximately 800 jobs would be lost. Because these jobs would be spread over 72 commercial and 5 DOE sites (about 10 jobs per site), socioeconomic impacts would be very small for a given region.

7.3.2.7 Occupational and Public Health and Safety

7.3.2.7.1 *Nonradiation Exposures*

For Scenario 1, Module 1, as with the Proposed Action, maintenance, repairs, repackaging, and construction at the storage facilities would be conducted in accordance with Occupational Health and Safety Administration and National Institute of Occupational Safety and Health requirements (29 CFR). Worker exposures to industrial nonradioactive hazardous materials during construction and operation of the storage facilities would be minimized through administrative controls and design features such that exposures would remain below hazardous levels.

For long-term impacts from Scenario 2, the increased inventory of Module 1 and resultant increase in stainless steel storage canisters would be likely to result in a proportional increase in concentrations of chemically toxic materials (such as chromium) in the groundwater and surface waters at the storage sites. However, as discussed in Section 7.2.2.5.1, these concentrations would remain extremely low and would not result in adverse human health impacts. In addition, as discussed in Section 7.2.2.5.1, the Department did not attempt to evaluate adverse health impacts resulting from dissolution of chemically toxic waste forms because it did not want to overestimate impacts from the No-Action Alternative.

7.3.2.7.2 *Industrial Hazards*

For Scenario 1, as discussed in Section 7.2.1.7.2, the majority of the industrial accidents would occur as a result of surveillance (about 94 percent) and construction tasks. Operations tasks would contribute less than 0.001 percent of the total number of accidents. Therefore, to estimate the number of industrial accidents that would be likely to occur at the storage sites for the Module 1 inventory, the number of additional concrete storage modules required to store the additional inventory was calculated.

For Module 1 during the approximately 100-year construction and operation cycle (2002 to 2116), about 80,000 full-time equivalent work years would be required to maintain about 11,000 concrete storage modules and 8 below-grade storage vaults at the 77 sites (DIRS 104596-Orthen 1999, Table 1). Based on this level of effort, as listed in Table 7-10, about 2,800 industrial safety incidents would be likely, resulting in about 1,200 lost workday cases and 3 fatalities (an average of about 1 fatality every 30 years).

Table 7-10. Estimated Module 1 industrial safety impacts at commercial and DOE sites during the first 100 years and the remaining 9,900-year period of analysis under Scenario 1.[a]

Industrial safety impacts	Short-term (100 years)[b] construction and operation	Long-term (9,900 years)[c] construction and operation
Total recordable cases	2,800	410,000
Lost workday cases	1,200	180,000
Fatalities	3	490

a. Source: DIRS 104596-Orthen (1999, Tables 6 and 7).
b. The estimated impacts would result from a single 100-year period of storage module construction (renovation), operation, surveillance, and maintenance.
c. Period from 100 to 10,000 years.

In addition, for Module 1, Table 7-10 indicates about 410,000 projected industrial safety incidents, of which about 180,000 would be lost workday cases and 490 would involve fatalities (an average of about 1 fatality every 20 years or about 1 every 1,600 years at each of the 77 sites). Surveillance tasks would provide about 94 percent of the total worker level of effort, construction tasks would provide nearly all of the remaining 6 percent, and operations tasks would provide less than 0.001 percent.

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7.3.2.7.3 *Radiation Exposures*

For Scenario 1, radiation exposures to offsite populations, involved workers, and noninvolved workers would increase because of the additional Module 1 inventory and the construction of additional facilities required to store the materials. The analysis assumed that radiation exposures to offsite and noninvolved worker individuals would increase by the ratio of the Module 1 inventory to the Proposed Action inventory, a factor of about 1.7. Radiation dose rates for the involved maximally exposed worker (construction) would not increase because of the self-shielding effect of the concrete storage modules. Table 7-11 lists radiological human health impacts resulting from the Module 1 inventory.

Table 7-11. Estimated Module 1 radiological human health impacts for Scenario 1.[a]

Receptor	Short-term (100 years) construction and operation	Long-term (9,900 years) construction[b] and operation
Population[c]		
MEI[d] (millirem per year)	0.34	0.10
Dose[e] (person-rem)	1,400	8,800
LCFs[f]	0.70	4.4
Involved workers[g]		
MEI[h] (millirem per year)	170	50
Dose (person-rem)	4,700	41,000
LCFs	1.9	16
Noninvolved workers[i]		
MEI[j] (millirem per year)	23	0[k]
Dose (person-rem)	61,000	0[k]
LCFs	25	0[k]

a. Source: Adapted from DIRS 101898-NRC (1991, all); DIRS 104596-Orthen (1999, all).
b. Assumes construction of 11,000 concrete storage modules, 1 above-grade vault, and 8 below-grade vaults at 77 sites (DIRS 104596-Orthen 1999, Table 1) every 100 years.
c. Members of the general public living within 3 kilometers (2 miles) of the facilities; estimated to be 140,000 over the first approximately 100 years and approximately 14 million over the 9,900-year long-term analysis period [estimated using DIRS 102204-Humphreys, Rollstin, and Ridgely (1997, all)].
d. MEI = maximally exposed individual; assumed to be approximately 1.4 kilometers (0.8 mile) from the center of the storage facility (DIRS 101898-NRC 1991, p. 22).
e. Estimated doses account for radioactive decay.
f. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0004 and 0.0005 latent cancer per rem for workers and members of the public, respectively (DIRS 101857-NCRP 1993, p. 112), and a life expectancy of 70 years for a member of the public and a 50-year career for workers.
g. Involved workers would be those directly associated with construction and operation activities (DIRS 101898-NRC 1991, pp. 23 to 25). For this analysis, the involved worker population would be about 1,600 individuals (800 individuals at any one time) at 77 sites over 100 years (DIRS 104596-Orthen 1999, Table 6). This population would grow to more than 190,000 over 10,000 years.
h. Based on maximum construction dose rate of 0.11 millirem per hour and 1,500 hours per year (DIRS 101898-NRC 1991, p. 23).
i. Noninvolved workers would be employed at the powerplant but would not be associated with facility construction or operation. For this analysis, the noninvolved worker population would be 80,000 individuals who would receive exposure until the powerplants were decommissioned (50 years).
j. Based on a projected area workforce of 1,200 and an average estimated annual dose of 16 person-rem (DIRS 101898-NRC 1991, p. 24).
k. During this period the powerplants would have ended operation, so there would be no noninvolved workers.

As listed in Table 7-11, the estimated dose to the hypothetical maximally exposed offsite individual for the Module 1 inventory during the operational period between 2002 and 2116 would be about 0.34 millirem per year [adapted from DIRS 101898-NRC (1991, p. 22)]. For the remaining 9,900 years of the analysis period, the dose to the hypothetical maximally exposed individual would decrease to about 0.10 millirem per year because of radioactive decay of the source material. During about the first

100 years, the dose (accounting for radioactive decay) could result (over a 70-year lifetime of exposure) in an increase in the lifetime risk of contracting a fatal cancer of 0.0000073, an increase over the lifetime natural fatal cancer incidence rate of 0.0031 percent. During the remaining 9,900 years of the analysis period, the dose (accounting for radioactive decay) could result (over a 70-year lifetime of exposure) in an increase in the lifetime risk of contracting a fatal cancer of 0.0000022, an increase over the lifetime natural fatal cancer incidence rate of 0.00092 percent.

For the short-term impacts, over about the first 100 years the offsite exposed population of approximately 140,000 would be likely to receive a total collective dose of 1,400 person-rem (adjusted for radioactive decay). This dose could result in 0.70 latent cancer fatality in addition to the 33,000 fatal cancers likely in the exposed population from all other causes. This represents an increase of about 0.0021 percent over the estimated number of cancer fatalities that would occur in the exposed population from all other causes.

For the long-term impacts from Scenario 1, the radiation dose of 8,800 person-rem from the storage facilities could result in an additional 4.4 latent cancer fatalities in the surrounding population of about 14 million. This would be in addition to about 3.3 million cancer fatalities that would be likely to occur in the exposed population of 14 million, an increase of 0.00013 percent over the natural incidence rate.

The analysis assumed the maximally exposed individual in the involved worker population would be a construction worker involved with construction and loading of replacement facilities. Assuming a maximum dose rate of 0.11 millirem per hour (unchanged from the Proposed Action) and an average exposure time of 1,500 hours per year, this construction worker would receive about 170 millirem per year. During about the first 100 years, this dose could result (over three years of construction) in an increase in the lifetime risk of contracting a fatal cancer of 0.00020, an increase of 0.09 percent over the natural fatal cancer incidence rate. During the remaining 9,900 years of the analysis period, the dose could result (over three years of construction) in an increase in the risk of contracting a fatal cancer of 0.000060, an increase over the natural fatal cancer incidence rate of 0.03 percent.

For the involved worker population of 1,600 individuals, approximately 380 would be likely to contract a fatal cancer from some cause other than occupational exposure. In the involved population of 1,600 storage facility workers (during the first 100 years), the collective dose of 4,700 person-rem (corrected for radioactive decay) between 2002 and 2116 could result in 1.9 additional latent cancer fatalities (DIRS 104596-Orthen 1999, Table 6), which would result in an increase of 0.51 percent over the natural incidence rate of fatal cancers from all causes. During the remaining 9,900 years of the analysis period, the involved estimated worker population of more than 190,000 would receive a collective dose of about 41,000 person-rem (corrected for radioactive decay). This dose could result in 16 latent cancer fatalities in addition to the 45,000 cancer fatalities that would be likely in the exposed population from all other causes. These additional cancers would represent an increase of 0.036 percent over the natural incidence rate of fatal cancers.

The estimated Module 1 collective dose to noninvolved workers at a nuclear powerplant from the Module 1 inventory would be about 27 person-rem per year [adapted from DIRS 101898-NRC (1991, p. 24)] for the protected area workforce of 1,200 individuals (DIRS 101898-NRC 1991, p. 26) at the two-unit station at Calvert Cliffs. This collective dose would result in an average maximum dose to the noninvolved worker of 23 millirem per year. Over a 50-year career, this exposure (corrected for radioactive decay) could result in an increase in the lifetime risk of contracting a fatal cancer of 0.00032. This incremental increase in risk would represent an increase of 0.13 percent over the incidence of fatal cancers from all other causes.

In the total noninvolved worker population of 80,000 powerplant workers (all sites), the estimated Module 1 collective dose of 61,000 person-rem (corrected for decay) between 2002 and 2116 could result in 25 additional latent cancer fatalities. This increase represents about an 0.13-percent increase over the 19,000 cancer fatalities that would be likely to occur from all other causes in the same worker population.

After about 100 years, Scenario 2 assumes no effective institutional control of the 77 sites and assumes that the storage facilities would be abandoned. Therefore, there would be no health risk for workers during that period. For the long-term impacts from Scenario 2, the analysis estimated human health impacts to the public on a regional basis (DIRS 104924-Poe 1999, p. 15). The estimated total population dose would increase from 6.6 million person-rem to about 7.3 million person-rem, resulting in an increase in the number of latent cancer fatalities from about 3,300 to almost 3,700 over the 9,900-year analysis period. Appendix K (Sections K.2.4.1 and K.3.1) contains details of the Proposed Action analysis.

7.3.2.8 Accidents

For Scenario 1, both short- and long-term accident consequences for the additional inventory of Module 1 would be bounded by the severe seismic event and could result in slightly higher impacts than those predicted for the Proposed Action inventory. However, this accident scenario would probably produce only minor radiological impacts to persons in the immediate vicinity of the storage facility.

For Scenario 2, the long-term impacts for Module 1 would be the same as those for the Proposed Action (see Section 7.2.2.7) because only a single concrete storage module would be affected, regardless of inventory.

7.3.2.9 Noise

For Scenario 1, noise levels for the Module 1 inventory should not be noticeably greater than those for the Proposed Action. Therefore, the noise would not adversely affect the hearing of facility workers or frighten wildlife from the area.

For the long-term impacts from Scenario 2, as with the Proposed Action, no noise would emanate from the facilities; therefore, no adverse impacts would occur. For about the first 100 years, noise levels would be the same as those for Scenario 1.

7.3.2.10 Aesthetics

As for the Proposed Action, Scenario 1 impacts to aesthetic or scenic resources from storage facilities resulting from the Module 1 inventory would be unlikely. Though the inventory would be larger than that for the Proposed Action, Module 1 would still require only two adjacent locations at each site. Every 100 years, a new facility would be constructed on the idle site, and the storage containers would be transferred. The old facility would be demolished and the site would remain idle for the next 100 years.

For the long-term impacts from Scenario 2, aesthetics would not change until facilities began to degrade, at which time the aesthetic value of the sites would change.

7.3.2.11 Utilities, Energy, and Materials

For Scenario 1, decommissioning and reclamation activities every 100 years associated with the increased number of concrete storage modules required for the Module 1 inventory would consume slightly more diesel fuel, gasoline, and materials than those for the Proposed Action. However, as with the Proposed Action, much equipment and many materials would be salvaged and recycled. DOE would recycle building materials as practicable. Minimal surveillance activities would require some gasoline. Therefore, the increased Module 1 inventory would not adversely affect the utility, energy, or material resources of the region or the country.

For the long-term impacts from Scenario 2, as with the Proposed Action, DOE would not use utilities, energy, or materials after about 100 years and, therefore, impacts to these resources would be unlikely.

7.3.2.12 Waste Management

Under Scenario 1, the construction of new facilities and the demolition of old facilities every 100 years (and the one-time refurbishment of existing facilities after the first 50 years) would generate construction debris and sanitary and industrial solid waste. In addition, routine repairs and maintenance to the facilities and storage containers, routine radiological surveys, and overpacking of failed containers would generate sanitary and industrial solid and low-level radioactive wastes. Because there would not be a dedicated workforce at the storage facilities, only small amounts of sanitary wastes would be generated except during periods of construction. The greatest amount of waste would be generated during the demolition of facilities at the 72 commercial and 5 DOE storage sites every 100 years. The demolition of facilities once every 100 years at all the sites would generate, on average, an estimated 1.4 million cubic meters (1.8 million cubic yards) of nonhazardous demolition debris, recyclable steel, and potentially a small amount of low-level waste if a dry storage canister failed while in storage (DIRS 104596-Orthen 1999, Table 7). The debris and wastes would be disposed of at commercial or DOE disposal facilities across the Nation. The impacts to available capacity would be spread nationwide, thus minimizing impacts to a single disposal facility. The capacities of the disposal facilities would accommodate the wastes generated at the storage facilities.

For Scenario 2, demolition activities would terminate after about 100 years and, therefore, no additional long-term waste management impacts would be likely after this period.

7.3.2.13 Environmental Justice

For Scenario 1, the potential impacts of continued storage of the Module 1 inventory with institutional control would be minimal. Therefore, minority or low-income populations would not be disproportionately or adversely affected.

For the long-term impacts from Scenario 2, the increased number of facilities required to store the Module 1 inventory could adversely affect the nearby public to a degree greater than that for the Proposed Action inventory. As with the Proposed Action inventory, nearby minority or economically disadvantaged communities could experience disproportionately high and adverse human health impacts. In addition, financial considerations could make it more difficult for members of minority or low-income populations to obtain uncontaminated resources or to move away from contaminated soils and water. Because subsistence patterns vary for minority or low-income populations, members of these populations could be exposed to greater than average doses. The result of differing potentials for exposure could result in disproportionately high and adverse impacts to minority or low-income populations.

7.3.2.14 Traffic and Transportation

For Scenario 1, the estimated number of workers commuting to and from work would increase from about 700 to about 800 (DIRS 104596-Orthen 1999, Table 7). The analysis assumed that the number of personnel required for round-the-clock surveillance would not increase but would remain at two individuals per shift per site.

The estimated number of traffic fatalities, which DOE calculated using the assumptions of Section 7.2.1.14, would be approximately 7 for the first 100 years and would increase from about 730 to about 900 for the remaining 9,900 years (DIRS 104596-Orthen 1999, Table 7).

For about the first 100 years, there would be no fatalities from exhaust emissions because there would be no construction or demolition of facilities. For the remaining 9,900 years, trucks would travel over 2.2 billion kilometers (1.4 billion miles), resulting in approximately 31 prompt traffic fatalities (DIRS 103455-Saricks and Tompkins 1999, Table 4, p. 25) and about 0.2 latent fatality from vehicle exhaust emissions.

The long-term impacts from Scenario 2 would be the same as those estimated for the first 100 years under Scenario 1 for Module 1. After the first 100 years, there would be no traffic or transportation-related impacts because all activity would cease.

7.3.2.15 Sabotage

For Scenarios 1 and 2, the risk of intruder access at each of the 77 sites would be essentially the same for Module 1 as for the Proposed Action inventory because the number of sites would remain the same. Therefore, the difficulty of maintaining 77 sites over 100 or 10,000 years also would remain essentially unchanged.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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8

Cumulative Impacts

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8. CUMULATIVE IMPACTS

The Council on Environmental Quality regulations that implement the procedural provisions of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 *et seq.*), define a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). The term reasonably foreseeable refers to future actions for which there is a reasonable expectation that the action could occur, such as a proposed action under analysis, a project that has already started, or a future action that has obligated funding. Cumulative impacts can result from individually minor but collectively important actions taking place over a period of time. An evaluation of cumulative impacts is necessary to an understanding of the environmental implications of implementing the Proposed Action and is essential to the development of appropriate mitigation measures and the monitoring of their effectiveness.

DOE structured the cumulative impact assessments in this chapter by identifying actions that could have effects that coincided in time and space with the effects from the proposed repository and associated transportation activities. The identification of the relevant actions was based on reviews of resource, policy, development, land-use plans prepared by agencies at all levels of government and from private organizations, other environmental impact statements, environmental assessments, and Native American tribal meeting records. Consistent with Council on Environmental Quality regulations 40 CFR 1502.16(c) and 1506.2, in addition to the assessment of potential cumulative impacts, the analysis considered potential conflicts with plans issued by various governmental entities to the extent practicable and to the extent they provided relevant information.

Not all actions identified in this chapter would have cumulative impacts in all discipline areas. Potential impacts for such actions are discussed for the appropriate discipline areas. In some instances for which an action is reasonably foreseeable, quantitative estimates of impacts are not possible because the action is in its early stages. For those actions, DOE acknowledges the project and states that potential cumulative impacts are unknown at this time.

This chapter evaluates the environmental impacts of repository activities coupled with the impacts of other Federal, non-Federal, and private actions. As part of this process, the chapter includes a detailed analysis of nuclear materials in need of permanent disposal in excess of those evaluated in the Proposed Action. It describes and evaluates these waste quantities, referred to as Inventory Modules 1 and 2, evaluated in terms of their environmental impacts in comparison with those of the Proposed Action impacts. The evaluation of these inventories provides sufficient information for future actions and decisionmaking on inventory selection. This chapter evaluates cumulative short-term impacts from the construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain, and cumulative long-term impacts following repository closure. It also evaluates cumulative transportation impacts from the shipment of spent nuclear fuel and high-level radioactive waste to the repository and of other material to or from the repository. The analysis of cumulative transportation impacts includes the possible construction and operation in Nevada of a branch rail line, or of an intermodal transfer station along with highway improvements for heavy-haul trucks. In addition, the analysis considers cumulative impacts from the manufacturing of repository components.

The cumulative impact analysis in this chapter includes as a reasonably foreseeable future action the disposal in the proposed Yucca Mountain Repository of the total projected inventory of commercial spent nuclear fuel, U.S. Department of Energy (DOE) spent nuclear fuel, and high-level radioactive waste, as well as the disposal of commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste. The total projected inventory of spent nuclear fuel and high-level radioactive waste is more than the 70,000 metric tons of heavy metal (MTHM) considered for the

Proposed Action. Its emplacement at Yucca Mountain would require legislative action by Congress unless a second licensed repository was in operation.

There were several reasons to evaluate the potential for disposing of Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste at Yucca Mountain as reasonably foreseeable actions. First, because both materials exceed Class C limits for specific radionuclide concentrations as defined in 10 CFR Part 61, they are generally unsuitable for near-surface disposal. Second, the U.S. Nuclear Regulatory Commission specifies in 10 CFR 61.55(a)(2)(iv) the disposal of Greater-Than-Class-C waste in a repository unless the Commission approved of disposal elsewhere. Finally, during the scoping process for this environmental impact statement (EIS), several commenters requested that DOE evaluate the disposal of other radioactive waste types that might require isolation in a repository. The disposal of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes at the proposed Yucca Mountain Repository could require a determination by the Nuclear Regulatory Commission that these wastes require permanent isolation. In addition to spent nuclear fuel, high-level radioactive waste, surplus plutonium, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste (materials such as depleted uranium), other radioactive wastes could be considered in the future for disposal in the Yucca Mountain Repository.

By analyzing the emplacement of Inventory Module 1 or 2, DOE is not stating that the emplacement of materials beyond those prescribed for the Proposed Action would occur. Rather, the Department is being prudent in analyzing a reasonably foreseeable action that could take place. If a future decision was made to emplace additional material included in the Inventory Modules, the Department would ensure that appropriate National Environmental Policy Act reviews were performed.

In general, the analysis of cumulative impacts in this chapter follows the process recommended in the Council on Environmental Quality's handbook *Considering Cumulative Effects Under the National Environmental Policy Act* (DIRS 103162-CEQ 1997, all). This process includes the identification, through research and consultations, of Federal, non-Federal, and private actions with possible effects that would be coincident with those of the Proposed Action on resources, ecosystems, and human communities. Coincident effects would be possible if the geographic and time boundaries for the effects of the Proposed Action and past, present, and reasonably foreseeable future actions overlapped. Using the methods and criteria described in Chapters 4, 5, and 6 of this EIS and their supporting appendixes, DOE assessed the potential cumulative impacts of coincident effects.

This chapter has six sections. Section 8.1 identifies and analyzes past, present, and reasonably foreseeable future actions with impacts that could combine with impacts of the Proposed Action. Sections 8.2 and 8.3 present the analyses of cumulative short-term (the period before the completion of repository closure) and long-term (the first 10,000 and first 1 million years following closure) impacts, respectively, in the proposed Yucca Mountain Repository region. Section 8.4 describes cumulative transportation impacts, nationally and in Nevada. Section 8.5 addresses cumulative impacts associated with the manufacturing of repository components. Section 8.6 presents an overall summary of potential cumulative impacts by discipline area.

8.1 Past, Present, and Reasonably Foreseeable Future Actions

This section identifies past, present, and reasonably foreseeable future actions with impacts that could combine with impacts of the Proposed Action. It describes these actions and their relationships to the Proposed Action that could result in cumulative impacts (see Table 8-1 for a summary). Sections 8.2 through 8.5 present the cumulative impacts from the past, present, and reasonably foreseeable future actions identified in this section.

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Table 8-1. Past, present, and reasonably foreseeable future actions that could result in cumulative impacts (page 1 of 3).

Name and action description	Potential cumulative impact areas: Short-term (Section 8.2)	Long-term (Section 8.3)	Transportation (Section 8.4)[a]	Manufacturing (Section 8.5)
Past and present actions[b]				
Nevada Test Site				
Nuclear weapons testing, waste management, etc.	Air quality and public health and safety[b]	Air quality, groundwater, and public health and safety	Occupational and public radiological health and safety	None
Beatty Waste Disposal Area				
Low-level radioactive and hazardous waste disposal	None	Groundwater and public health and safety	Occupational and public radiological health and safety	None
Reasonably foreseeable future actions				
Inventory Module 1[c]				
Disposal of all spent nuclear fuel and high-level radioactive waste in the proposed Yucca Mountain Repository	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)
Inventory Module 2[c]				
Disposal of all spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class C waste and Special-Performance-Assessment-Required waste, in the proposed Yucca Mountain Repository	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)
Nellis Air Force Range				
National testing and training for military equipment and personnel	None	None	Land use	None
Nevada Test Site				
Defense (stockpile stewardship and management, material disposition, nuclear emergency response), waste management, environmental restoration, nondefense research and development, work for others	Air quality, groundwater, socioeconomics, public health and safety. (Note: The accident analysis of potential external events in Appendix H addresses the effects of possible future resumption of nuclear weapons tests).	Groundwater and public health and safety	Occupational and public radiological health and safety	None
Nevada Test Site				
Alternative Energy Generation Facility	*Land use, utilities*	None	None	None
DOE Complex-Wide Waste Management Activities Affecting the Nevada Test Site				
Treatment, storage, and disposal of low-level radioactive waste, mixed waste, transuranic waste, high-level radioactive waste, and hazardous waste from past and future nuclear defense and research activities	No additional[d] beyond those analyzed for Nevada Test Site activities	Groundwater and public health and safety	Occupational and public radiological health and safety	None

Table 8-1. Past, present, and reasonably foreseeable future actions that could result in cumulative impacts (page 2 of 3).

Name and action description	Short-term (Section 8.2)	Long-term (Section 8.3)	Transportation (Section 8.4)[a]	Manufacturing (Section 8.5)
	Potential cumulative impact areas			
Reasonably foreseeable future actions (continued)				
Low-Level Waste Intermodal Transfer Station				
Construction and operation of an intermodal transfer station for the shipment of low-level radioactive waste to the Nevada Test Site near Caliente	None	None	Same resource areas as the Proposed Action (see Table 8-5) (Caliente intermodal transfer station and highway route for heavy-haul trucks)	None
Timbisha Shoshone Reservation				
Creation and development of a discontiguous reservation in eastern California and southwestern Nevada	Land use, groundwater	None	Water consumption, land use, public safety, environmental justice	None
Cortez Pipeline Gold Deposit Projects				
Continued operation and potential expansion of a gold mine and processing facility	None	None	Land use and ownership (Carlin rail corridor)	None
Apex Bulk Commodities Intermodal Transfer Station				
Construction and operation of an intermodal transfer station for copper concentrate near Caliente	None	None	Same resource areas as the Proposed Action (see Table 8-5) (Caliente intermodal transfer station and highway route for heavy-haul trucks)	None
Shared use of a DOE branch rail line				
Increase in rail operations and traffic resulting from rail service options for nearby mine operators and communities	None	None	Same resource areas as the Proposed Action (see Table 8-5)	None
Private Fuel Storage				
Temporary storage of spent nuclear fuel at the Goshute Reservation in Utah	None	None	Occupational and public radiological health and safety	None
Owl Creek Energy Project				
Temporary storage of spent nuclear fuel	None	None	Potential occupational and public radiological health and safety	None
Ivanpah Airport				
Construction of an airport on previously undisturbed land	None	None	Land use (Jean transportation corridor)	None
Moapa Paiute Energy Center				
Lease land and water use for construction of a coal-fired powerplant	None	None	Land use	None

Table 8-1. Past, present, and reasonably foreseeable future actions that could result in cumulative impacts (page 3 of 3).

	Potential cumulative impact areas			
Name and action description	Short-term (Section 8.2)	Long-term (Section 8.3)	Transportation (Section 8.4)[a]	Manufacturing (Section 8.5)
Reasonably foreseeable future actions (continued)				
Southern Nevada Public Land Management Act				
Convey approximately 110 square kilometers[e] of Bureau of Land Management lands to commercial and private entities	Land use and ownership	None	Land use and ownership	None
Desert Space Station Science Museum				
Construct an 8,800-square-meter[f] science museum on land acquired from the Bureau of Land Management	Land use	None	None	None

a. In addition to the specific actions identified in Section 8.1 and summarized in this table, the cumulative impacts for national transportation consider the occupational and public radiological health impacts of other past, present, and reasonably foreseeable future shipments of radioactive material.
b. The impacts of most past and present actions are included in the existing environmental baseline described in Chapter 3 and, therefore, are generally encompassed in the analysis of potential impacts of the Proposed Action in Chapters 4, 5, and 6. This includes site characterization activities at Yucca Mountain.
c. As described in Section 8.1.2.1, there would be essentially no difference in the design and operation of the repository for Inventory Module 1 or 2. Therefore, the cumulative impacts from Inventory Module 1 are generally considered the same as those from Inventory Module 2.
d. DOE waste management activities at the Nevada Test Site are included for the continuation of waste management activities at current levels, plus additional wastes that could be received as a result of decisions based on the Waste Management Programmatic EIS (DIRS 101816-DOE 1997, all). This includes cumulative impacts of transportation and disposal.
e. 110 square kilometers = 27,000 acres.
f. 8,800 square meters = 95,000 square feet.

8.1.1 PAST AND PRESENT ACTIONS

The description of existing (baseline) environmental conditions in Chapter 3 includes the impacts of most past and present actions on the environment that the Proposed Action would affect. This includes site characterization activities at Yucca Mountain. The impacts of past and present actions are, therefore, generally encompassed in the Chapter 4, 5, and 6 analyses of potential environmental impacts of the Proposed Action because the baseline for these analyses is the affected environment described in Chapter 3.

Two past actions that are not addressed in the Chapter 3 environmental baseline were identified for inclusion in the cumulative impact analysis in Sections 8.2, 8.3, and 8.4—past DOE activities at the Nevada Test Site (nuclear weapons testing, etc.) and past disposal of low-level radioactive waste at the Beatty Waste Disposal Area. Resources identified where past Nevada Test Site activities could add to impacts from the Proposed Action include air quality, groundwater, public health and safety, and transportation. For the Beatty Waste Disposal Site, the analysis included potential cumulative impacts from past transportation of waste to the Beatty site and from potential groundwater contamination.

Other actions that are presently occurring also have a component that is reasonably foreseeable as a future action. These are discussed in Section 8.1.2.

8.1.2 REASONABLY FORESEEABLE FUTURE ACTIONS

This section describes the reasonably foreseeable future actions that the cumulative impacts analysis considered. The analysis included cumulative impacts from the disposal in the proposed repository of all projected spent nuclear fuel and high-level radioactive waste as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste as reasonably foreseeable future actions (Inventory Modules 1 and 2; see Section 8.1.2.1). Sections 8.1.2.2 and 8.1.2.3 describe other Federal, non-Federal, and private actions that could result in cumulative impacts. This chapter does not discuss cumulative impacts for the No-Action Alternative. Chapter 7, Section 7.3, describes those impacts. Chapters 2 and 7 contain details on the No-Action Alternative and on continued storage of the material at its current locations or at one or more centralized location(s).

DOE gathered information on Federal, non-Federal, and private actions to identify reasonably foreseeable future actions that could combine with the Proposed Action to produce cumulative impacts. The types of documents reviewed included other EISs, resource management plans, environmental assessments, Notices of Intent, Records of Decision, etc. Consultations with Federal agencies, state and local agencies, and Native American tribes (see Appendix C) also contributed to the information used in the cumulative impact analysis.

8.1.2.1 Inventory Modules 1 and 2

Under the Proposed Action, DOE would emplace in the proposed Yucca Mountain Repository as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. Of the 70,000 MTHM, approximately 63,000 MTHM would be commercial spent nuclear fuel. The remaining 7,000 MTHM would consist of approximately 2,333 MTHM of DOE spent nuclear fuel and approximately 8,315 canisters (4,667 MTHM) containing solidified high-level radioactive waste (commercial and defense-related). To determine the number of canisters of high-level radioactive waste included in the Proposed Action waste inventory, DOE used an equivalence of 2.3 MTHM per canister of commercial high-level radioactive waste and 0.5 MTHM per canister of defense high-level radioactive waste as discussed in Appendix A, Section A.2.3.1. DOE has consistently used the 0.5-MTHM-per-canister equivalence since 1985. Using a different approach would change the number of canisters of high-level radioactive waste analyzed for the Proposed Action. Regardless of the number of canisters, the impacts from the entire inventory of high-level radioactive waste are analyzed in this chapter. In addition, the 70,000 MTHM inventory would include an amount of surplus plutonium as spent mixed-oxide fuel or immobilized plutonium.

Inventory Modules 1 and 2 represent the reasonably foreseeable future actions of disposing of all projected commercial and DOE spent nuclear fuel and all high-level radioactive waste as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in the proposed repository (see Figure 8-1). Under Inventory Module 1, DOE would emplace all projected commercial spent nuclear fuel (about 105,000 MTHM), all DOE spent nuclear fuel (about 2,500 MTHM), and all high-level radioactive waste (approximately 22,280 canisters). Inventory Module 2 includes the Module 1 inventory plus other radioactive material that could require disposal in a monitored geologic repository (commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste). The estimated quantities of these other wastes are about 2,000 cubic meters (71,000 cubic feet) and about 4,000 cubic meters (140,000 cubic feet), respectively. Appendix A contains further details on these inventories.

The following paragraphs summarize the differences in repository facilities and operations to receive, package, and emplace the additional materials in Inventory Module 1 or 2. The information on Modules 1 and 2 in this section is from CRWMS M&O (DIRS 104508-1999, DIRS 104523-1999, and DIRS 102030-1999) unless otherwise noted. Table 8-2 summarizes the increased number of shipments that would be required to transport the Module 1 or 2 inventory to the repository. As for the Proposed Action, the estimated numbers of shipments were based on the characteristics of the materials, shipping capabilities at the commercial nuclear sites and DOE facilities, the assumption that there would be one shipping cask per truck or railcar (a train would normally use multiple rail cars and ship more than one

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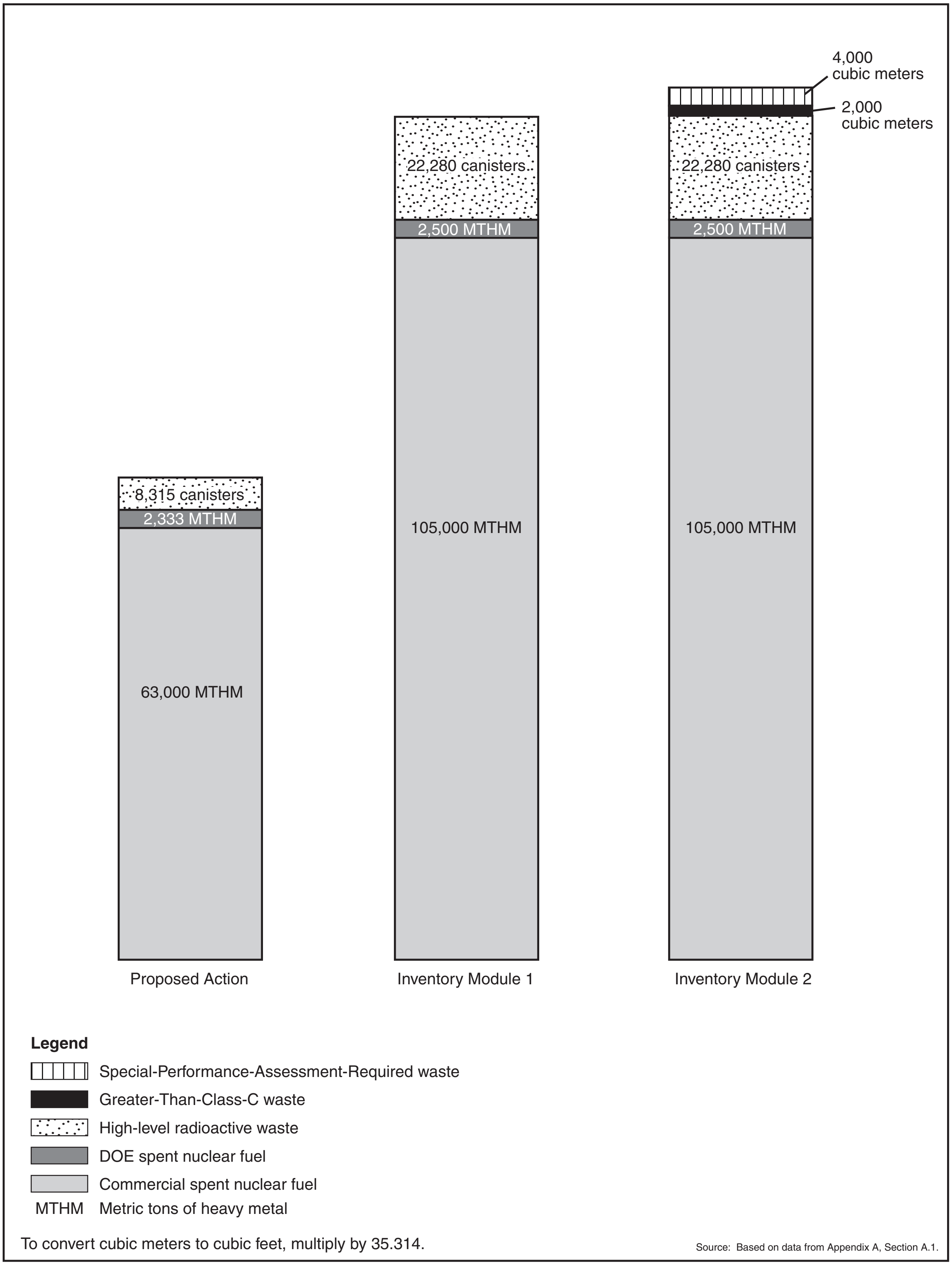

Figure 8-1. Proposed Action, Module 1, and Module 2 inventories evaluated for emplacement in a repository at Yucca Mountain.

Table 8-2. Estimated number of shipments for the Proposed Action and Inventory Modules 1 and 2.[a,b]

	Proposed Action				Module 1				Module 2			
	Mostly legal-weight truck		Mostly rail		Mostly legal-weight truck		Mostly rail		Mostly legal-weight truck		Mostly rail	
Material	Truck	Rail[c]	Truck	Rail	Truck	Rail	Truck	Rail	Truck	Rail	Truck	Rail
Commercial SNF[d]	41,000	0	1,100	7,200	80,000	0	3,100	13,000	80,000	0	3,100	13,000
DOE SNF	3,500	300	0	770	3,700	300	0	800	3,700	300	0	800
HLW[e]	8,300	0	0	1,700	22,000	0	0	4,500	22,000	0	0	4,500
GTCC[f] waste	0	0	0	0	0	0	0	0	1,100	0	0	280
SPAR[g] waste	0	0	0	0	0	0	0	0	1,800	55	0	410
Totals	***53,000***	***300***	***1,100***	***9,700***	***110,000***	***300***	***3,100***	***18,000***	***109,000***	***360***	***3,100***	***19,000***

a. Source: Appendix J, Section J.1.3.1.
b. Totals might differ from sums of values due to rounding.
c. For this EIS, each combination of a shipping cask and railcar is assumed to be a single shipment.
d. SNF = spent nuclear fuel.
e. HLW = high-level radioactive waste.
f. GTCC = Greater-Than-Class-C.
g. SPAR = Special-Performance-Assessment-Required.

cask), various cask designs, and the transportation mode mix (mostly legal-weight truck or mostly rail). Appendix J contains additional details on Inventory Module 1 and 2 transportation requirements.

The following are the major differences between the repository facilities and operations for Inventory Modules 1 and 2 and those for the Proposed Action, which are described in Chapter 2:

- The longer time required to receive, package, and emplace the additional spent nuclear fuel, high-level radioactive waste, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste, and to close the repository, for Inventory Module 1 or 2 versus that for the Proposed Action. The periods for the various project phases for Inventory Modules 1 and 2 would be the same.

- The need for more subsurface area to emplace about 17,000 to 26,000 waste packages for the Inventory Modules in comparison to about 11,000 to 17,000 waste packages for the Proposed Action.

Table 8-3 lists the differences in the expected time sequence for the repository construction, operation and monitoring, and closure phases for the Proposed Action and the Inventory Modules. DOE expects the construction phase to last for 5 years. Following this phase, repository development is projected to last for 22 years and emplacement for 24 years for the Proposed Action. During the operation and monitoring phase, development and emplacement is expected to last for 36 and 38 years, respectively, for Module 1 or Module 2. Monitoring activities during this phase would occur concurrently and then would extend beyond the emplacement period for up to 300 years. DOE expects the closure phase to last between 10 and 17 years for the Proposed Action and between 12 and 23 years for the Inventory Modules.

Table 8-3. Expected time sequence (years) of Yucca Mountain Repository phases for the Proposed Action and Inventory Module 1 or 2.

		Operation and monitoring phase			
Inventory	Construction phase	Development	Emplacement[a]	Monitoring	Closure phase
Proposed Action	5	22	24 - 50	76 - 300	10 - 17
Module 1 or 2	5	36	38 - 51	62 - 300	12 - 23

a. Range results from consideration of various operating modes with and without aging.

The amount of land required for surface facilities would increase only slightly for Inventory Module 1 or 2 from that for the Proposed Action (see Table 8-4). The design and operation of the repository surface facilities for Inventory Modules 1 and 2, including a Cask Maintenance Facility if it was at the Yucca Mountain site, would not differ much from those of the Proposed Action. The rate of material receipt,

Table 8-4. Amount of land (in square kilometers) newly disturbed at the proposed Yucca Mountain Repository for the Proposed Action and Inventory Module 1 or 2.[a,b,c]

Area	Proposed Action		Module 1 or 2	
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
North Portal Operations Area	0.62	0.62	0.62	0.62
South Portal Development Area	0.15	0.15	0.15	0.15
Ventilation Shaft Operations Areas and access roads	0.83 (7 shafts)	1.04 - 1.42 (10 - 17 shafts)	1.13 (11 shafts)	1.38 - 1.89 (16 - 25 shafts)
Excavated rock storage area	0.87	0.87 - 1.51	1.40	1.40 - 2.02
Landfill	0.04	0.04 - 0.06	0.04	0.04 - 0.06
Solar power generating facility	0.22	0.22	0.22	0.22
Concrete batch plant	0.06	0.06	0.06	0.06
Surface aging facility	0	0 - 0.47	0	0 - 0.47
Totals	***2.8***	***3.0 - 4.5***	***3.6***	***3.9 - 5.5***

a. Source: DIRS 152010-CRWMS M&O (2000, Table 6-2, p. 52); DIRS 150941-CRWMS M&O (2000, p. 4-9 and Figure 6-1, p. 6-27); DIRS 155515-Williams (2001, 2.1-m Spacing Option: p. 27 and 29; 6.4-m Spacing Option: p. 24); DIRS 155516-Williams (2001, p. 3); DIRS 153882-Griffith (2001, p. 8).

b. To convert square kilometers to acres, multiply by 247.1.

c. Totals might differ from sums of values due to rounding.

packaging, and emplacement would be approximately the same and would require an extra 14 years beyond the 24-year emplacement period for the Proposed Action. There would be no difference in the duration of the emplacement period between Inventory Modules 1 and 2 because the surface and subsurface facilities could accommodate the small number of additional shipments and waste packages for Module 2.

The repository subsurface facilities for Inventory Module 1 or 2 would require about 60 percent more subsurface excavation than the Proposed Action. About 7.2 square kilometers (1,790 acres) would be required for the higher-temperature repository operating mode for Module 1 or 2, and from 10 to 15.4 square kilometers (2,480 to 3,810 acres) for the lower-temperature mode for Module 1 or 2. This compares to about 4.6 square kilometers (1,150 acres) and from 6.5 to 10.4 square kilometers (1,600 to 2,570 acres) for the higher- and lower-temperature modes, respectively, for the Proposed Action. Additional subsurface area would be needed if maximum spacing was used to achieve the lower-temperature mode. DOE would characterize this additional subsurface area, which would be adjacent to the blocks identified for the Proposed Action, more fully before its use. The subsurface facilities would not differ between Inventory Modules 1 and 2 for the lower-temperature operating mode with maximum-spacing because DOE would place the additional waste packages for Greater-Than-Class C and Special-Performance-Assessment-Required wastes between commercial spent nuclear fuel waste packages. However, total drift length would have to be increased by an estimated 3.7 to 4.9 kilometers (2.3 to 3.0 miles) for the other methods to achieve the lower-temperature operating mode when going from Inventory Module 1 to Module 2. There would be no difference in emplacement operating for Inventory Module 1 or 2 from those described for the Proposed Action in Chapter 2 unless DOE used the lower-temperature mode with surface aging. Because of the extra time involved in receiving and emplacing the Module 1 or 2 waste, there would be no delay in the process with the aging option before movement of the aged waste to the subsurface could begin, and DOE could move it at a faster rate. Monitoring and maintenance activities for Inventory Module 1 or 2 would be comparable to those for the Proposed Action with the exception of their duration in some cases.

Because there would be an increase in the number of waste packages and the increased length of the drifts that would be necessary for Inventory Module 1 or 2, the duration of the closure phase would be longer for Module 1 or 2 (12 to 23 years) compared to 10 to 17 years for the Proposed Action (see Table 8-3).

Inventory Module 1 or 2 closure phase activities would not otherwise differ from those described in Chapter 2 for the Proposed Action.

As discussed in the introduction to this chapter, the Department is not proposing at this time to emplace the additional materials from the Inventory Modules in the repository. If a future proposal was made to emplace these materials, the Department would ensure that appropriate National Environmental Policy Act reviews were performed.

8.1.2.2 Federal Actions

The following paragraphs describe reasonably foreseeable future actions of Federal agencies that could result in cumulative impacts in addition to those from Inventory Module 1 or 2.

Nellis Air Force Range

The Nellis Air Force Range (also referred to as the Nevada Test and Training Range) in south-central Nevada (see Figure 8-2) is a national test and training facility for military equipment and personnel. The *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all) addresses the potential environmental consequences of the Air Force proposal to continue the Nellis Air Force Range land withdrawal for military use. As part of the actions analyzed in the Legislative EIS, the Air Force would renew its land withdrawal of almost 3 million acres and transfer responsibility to DOE for approximately 127,620 acres of land generally described as Pahute Mesa. Figures 8-2 and 8-3 show Pahute Mesa as part of the Nevada Test Site. The President signed S.1059 in October 1999, making it Public Law 106-65 and authorizing the renewed withdrawals and transfers described in the Legislative EIS.

The Air Force also issued the *Final Environmental Impact Statement F-22 Aircraft Force Development Evaluation and Weapons School Beddown at Nellis Air Force Base* in 1999 (DIRS 155928-Estrada 2001, all) to evaluate the potential impacts of locating F-22 aircraft at the Nellis Air Force Range. The action would entail the construction of some new facilities and other modifications to support the aircraft. The Record of Decision (DIRS 155918-Keck 1999, all) shows that the action "would result in either negligible effects or would not change current environmental conditions at Nellis AFB" for the major discipline areas. Therefore, DOE has not quantified potential cumulative impacts from this action. The descriptions of the affected environment in Chapter 3 and the potential impacts of the Proposed Action in Chapters 4, 5, and 6 include the effects of present activities at the Nellis Air Force Range.

Nevada Test Site

Several actions at the Nevada Test Site would pose a cumulative impact. Figure 8-3 shows a map of the Nevada Test Site to assist in identifying the location of these actions.

The *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all) examines current and future DOE activities in southern Nevada at the Nevada Test Site, Tonopah Test Range, and sites the Department formerly operated in Nevada. The first Record of Decision for that EIS (61 *FR* 65551, December 13, 1996) states that DOE would implement a combination of three alternatives: Expanded Use, No Action (continue operations at current levels) regarding mixed and low-level radioactive waste management, and Alternate Use of Withdrawn Lands regarding public education. On February 18, 2000, the Department issued an Amendment of the Record of Decision (65 *FR* 10061, February 26, 2000). In this Amendment, DOE decided, based on its National Environmental Policy Act reviews for the Nevada Test Site and for the Complex-wide waste management program described in the Programmatic Waste Management EIS (DIRS 101816-DOE 1997, all), to implement the Expanded Use Alternative for waste management activities at the Test Site, including mixed and low-level radioactive waste.

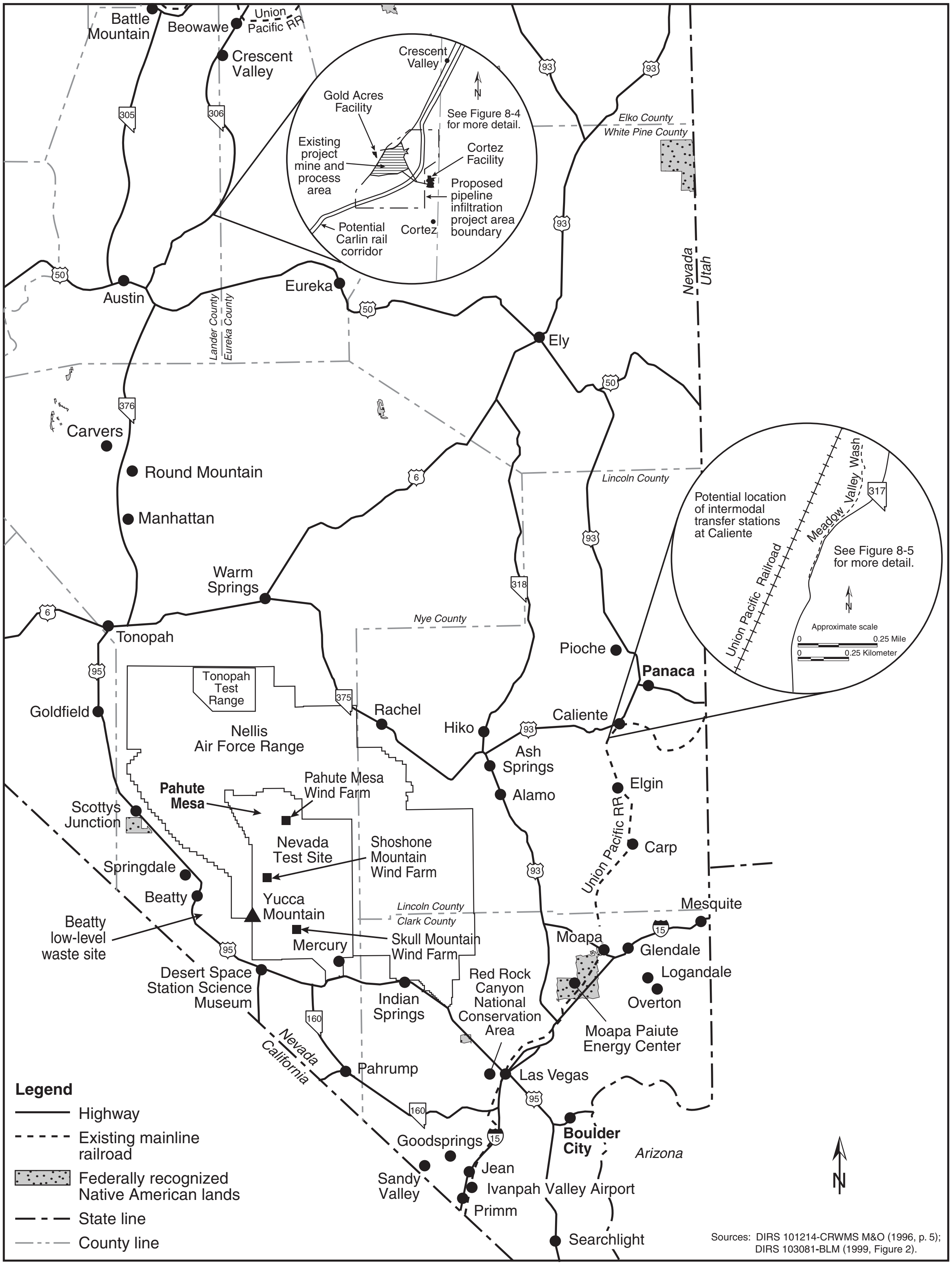

Figure 8-2. Locations of past, present, and reasonably forseeable future actions considered in the cumulative impact analysis.

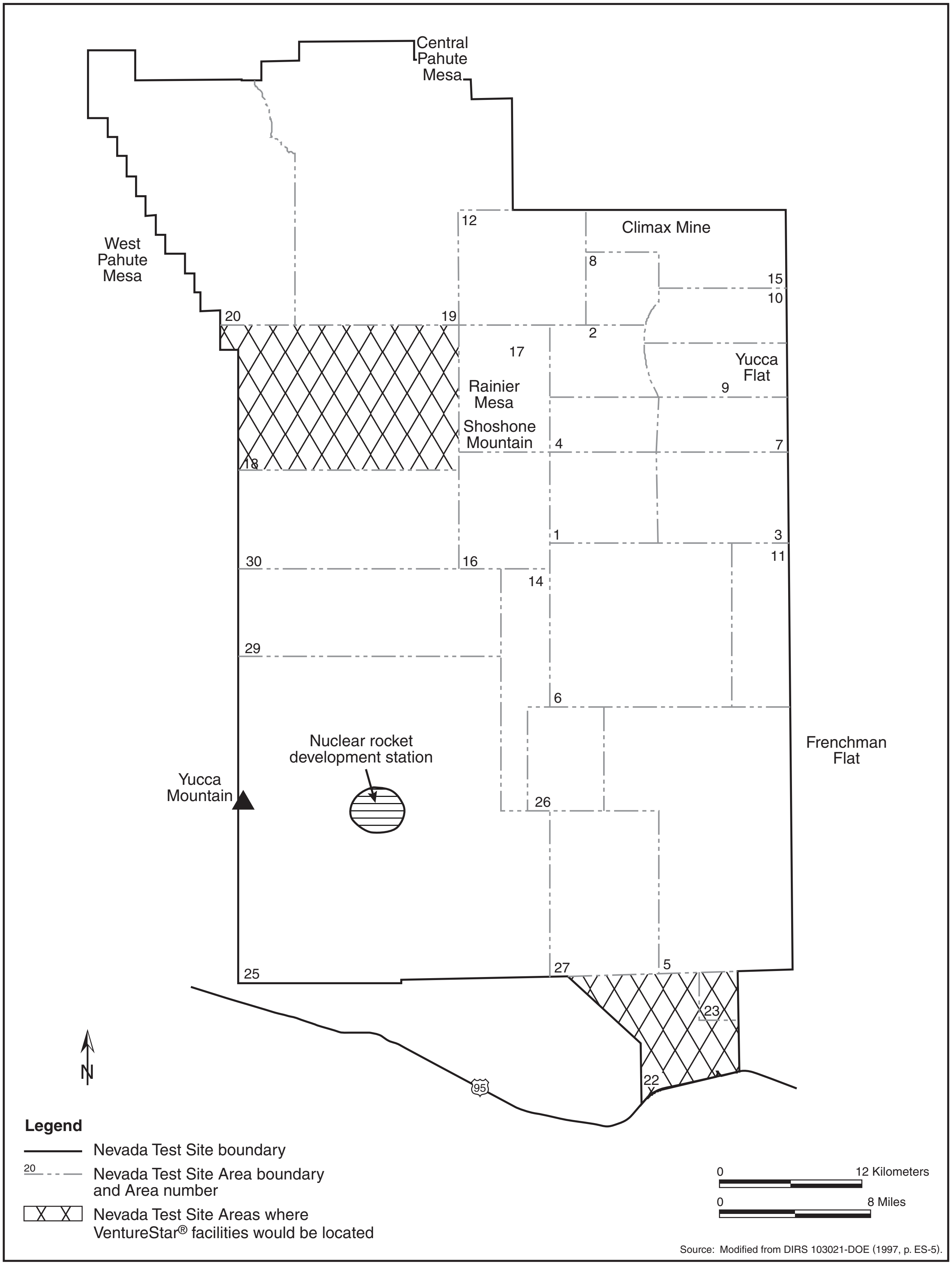

Figure 8-3. Potential locations of proposed cumulative activity associated with VentureStar®/Kistler at the Nevada Test Site.

The Expanded Use Alternative incorporates all the activities and operations from ongoing Nevada Test Site programs and increases some of those programs. Activities of the Office of Defense Programs would expand at both the Nevada Test Site and the Tonopah Test Range, primarily in the areas of stockpile stewardship and management, materials disposition, and nuclear emergency response. As part of the Stockpile Stewardship and Management Program, there are continuing *subcritical* weapons test activities to study aging of weapons components and their reliability after aging. Waste management activities would continue at current levels pending decisions by DOE based on the *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (DIRS 101816-DOE 1997, all). Based on the preferred alternative in the programmatic EIS, this cumulative impact analysis included the additional low-level and mixed waste that could come to the Nevada Test Site. The Environmental Restoration Program would continue, potentially at an accelerated rate, at the Nevada Test Site and all offsite locations. Under the Work for Others Program, military use of the airspace over the Nevada Test Site and the Tonopah Test Range would increase, as would the use of certain lands on the Nevada Test Site by the military for training, research, and development. Public education activities would include the possible construction of a museum that highlights Nevada Test Site testing activities. The Nevada Test Site Development Corporation is considering the VentureStar® program initiative from the Lockheed Martin Corporation for a launch/recovery system that would link with the Kistler Aerospace Satellite launch and recovery project. The VentureStar® program would require two spaceports, a manufacturing and assembly facility, and a payload processing and administrative complex. These activities could occur in Areas 18, 22, and 23, respectively (Figure 8-3). However, the Kistler aerospace activity is currently on hold (DIRS 152582-Davis 2000, all), and there is not enough information at this time to perform a cumulative impacts analysis for this project.

An analysis of the environmental impacts presented in the Nevada Test Site EIS (DIRS 101811-DOE 1996, all) (including impacts from weapons testing and the VentureStar®/Kistler project) identified the following resources for which impacts could overlap in relation to geography and timing with impacts from the proposed repository: air quality, groundwater, socioeconomics, public health and safety, and transportation. The effects on the Yucca Mountain Repository if a decision were made in the future to resume nuclear weapons testing or from a possible vehicle launch or recovery accident at the proposed VentureStar®/Kistler project are considered in the accident analysis of potential external events in Appendix H.

As discussed above in the section on the Nellis Air Force Range, part of the land previously assigned to the Range, specifically the parcel known as Pahute Mesa, has been transferred to the Nevada Test Site. The use of the land has not changed; this was a transfer of jurisdiction to match actual use with ownership.

A moratorium on the explosive testing of nuclear weapons began in October 1992. As discussed in the Nevada Test Site EIS, however, other testing continues at the Test Site, including dynamic, hydrodynamic, and explosive tests (DIRS 101811-DOE 1996, all). These tests are necessary for the continued assurance of the Nation’s nuclear arsenal but do not result in nuclear explosions like those that were common during the Cold War. Therefore, environmental contamination from nuclear weapons testing is largely due to past testing and not to current activities at the Test Site. Although there are potential past and present impacts of the explosive testing of nuclear weapons, the long-lived radionuclides that have been deposited far underground could pose future impacts that are evaluated in Section 8.3. As shown in that section, DOE has made conservative assumptions to ensure the identification of any potential cumulative impacts between the Nevada Test Site and the proposed repository.

In March 2000, DOE published the *Nevada Test Site Development Corporation’s Desert Rock Sky Park at the Nevada Test Site Environmental Assessment* (DIRS 155529-DOE 2000, all) and the associated

Finding of No Significant Impact. This environmental assessment evaluated the potential impacts of issuing a general use permit to the Nevada Test Site Development Corporation to develop, operate, and maintain a commercial/industrial park at the Test Site. The project would permit development of approximately 2 square kilometers (510 acres) of land already designated as a "private/commercial development zone."

In March 2001, DOE published the *Preapproval Draft Environmental Assessment for a Proposed Alternative Energy Generation Facility at the Nevada Test Site* (DIRS 154545-DOE 2001, all). The NTS Development Corporation (NTSDC) and the M&N Wind Power Inc. and Siemens (MNS) have requested authorization (under an easement between DOE and NTSDC and a subeasement between NTSDC and MNS) for the installation of 260 and 436 megawatts of a commercial wind-turbine-generated power system using as many as 545 wind turbine generators on three areas of the Nevada Test Site. The development of this system would allow for land use diversification of the Test Site by including nondefense and private use. The areas consist of the Shoshone Mountain Area, the Pahute Mesa, and Skull Mountain. DOE used these areas comprising 4.9 square kilometers (1,200 acres) for nuclear and conventional explosive testing facilities. The wind generators would be constructed on the ridges in these areas to maximize the effects of wind currents. They would be constructed in three phases and would not conflict with continued Nevada Test Site operations in the valley areas. On July 25, 2001, DOE announced its intention to prepare an EIS based on its analysis contained in the previous environmental assessment. This EIS would consider alternative locations and examine the impacts of the No-Action Alternative.

DOE Waste Management Activities

The Waste Management Programmatic EIS (DIRS 101816-DOE 1997, all) evaluates the environmental impacts of managing five types of radioactive and hazardous wastes generated by past and future nuclear defense and research activities at a variety of DOE sites in the United States. The five waste types are low-level radioactive waste, mixed low-level waste (referred to in this EIS as simply mixed waste), transuranic waste, high-level radioactive waste, and hazardous waste. The Waste Management Programmatic EIS provides information to assist DOE with decisions on the management of, and facilities for, the treatment, storage, and disposal of these radioactive, hazardous, and mixed wastes.

DOE has issued six Records of Decision or revisions to Records of Decision on the Programmatic Waste Management EIS (DIRS 101816-DOE 1997, all). The discussion of these decisions is presented in this section; however, the impacts of actions from these decisions would be related primarily to transportation of materials; these impacts are part of the analysis in Section 8.4. The first Record of Decision (63 *FR* 3629, January 23, 1998) announced the Department's decision to treat and store transuranic waste at each DOE facility except Sandia National Laboratory, which would transfer its transuranic waste to Los Alamos National Laboratory for preparation and storage. This waste would ultimately be disposed of in the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

The fourth Record of Decision announced the Department's decision to make the Nevada Test Site and the Hanford Site available to all DOE sites for disposal of low-level waste and mixed low-level waste. This decision was accompanied by an amendment to the Record of Decision for the Nevada Test Site EIS (65 *FR* 10061, February 25, 2000) to implement the Expanded Use Alternative from that EIS.

On December 29, 2000, the Department announced a revision (65 *FR* 82985) to its decision regarding transuranic waste. Under this decision, the Department would establish at the Waste Isolation Pilot Plant the capability to prepare transuranic waste for disposal. In addition, the above-ground capacity at the Waste Isolation Pilot Plant would be increased by 25 percent.

On July 25, 2001, the Department issued (66 *FR* 38646) a further revision to its previous decision by announcing its decision to transfer about 300 cubic meters of transuranic waste from the Mound facility in Miamisburg, Ohio, to the Savannah River Site for storage, characterization, and repackaging prior to sending it to the Waste Isolation Pilot Plant.

The *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement* (DIRS 101814-DOE 1997, Chapter 5) identifies potential cumulative transportation impacts from the shipment of transuranic wastes from DOE sites across the United States, including the Nevada Test Site, to the Waste Isolation Pilot Plant in southeastern New Mexico for disposal.

Low-Level Waste Intermodal Transfer Station

DOE prepared a draft environmental assessment (DIRS 103225-DOE 1998, all) on a proposed action to encourage low-level radioactive waste generators and their contractors to use transportation alternatives that would minimize radiological risk, enhance safety, and reduce the cost of waste shipments to the Nevada Test Site. However, DOE determined that there was no decision for it to make relative to transportation of low-level radioactive waste that would require a National Environmental Policy Act analysis, and therefore no longer plans to issue a National Environmental Policy Act document. DOE has published a technical report that provides its low-level radioactive waste generators with a comparative risk analysis of alternative highway routes and intermodal transportation facilities (DIRS 155779-DOE 1999, all).

Road improvements to accommodate legal-weight trucks and the construction of a rail siding or spur on a 0.02-square-kilometer (5-acre) site 1.2 kilometers (0.75 mile) south of Caliente would be needed for the low-level radioactive waste intermodal transfer station. Lifting equipment (crane or forklift) would transfer containers of low-level radioactive waste from railcars to trucks for transport to the Nevada Test Site. Based on a 10-year average estimate of low-level waste volumes and shipments for the expanded use alternative from the Nevada Test Site EIS (DIRS 101811-DOE 1996, pp. 5-110 to 5-112), DOE expects the traffic through the intermodal transfer station to be less than 3 trains per day and about 14 trucks per day (7 outbound from the station and 7 returning from the Nevada Test Site). Intermodal transfer operations would occur only during daytime working hours, with containers dropped off during the night transported to the Nevada Test Site the following morning. A staff of three would be adequate to conduct operations at the station. Trucks would be inspected and decontaminated, as necessary, at the Nevada Test Site before returning to the station (DIRS 103225-DOE 1998, pp. 2-1 to 2-10 unless otherwise noted).

A high-end estimate for the planned trucking operation to support the low-level radioactive waste intermodal transfer station indicates a terminal on about 0.04 to 0.06 square kilometer (10 to 15 acres), a maintenance building 21 by 23 meters (70 by 75 feet), 9 tractors and 27 trailers, and 11 employees. One proposed location would be south and just outside of Caliente. Trucks would not pass through the Town of Caliente to reach the intermodal transfer station site (DIRS 103225-DOE 1998, p. 5-4).

The projections of low-level radioactive waste shipments from current DOE-approved generators to the Nevada Test Site do not extend to 2010 when shipments of spent nuclear fuel and high-level radioactive waste would begin to the proposed Yucca Mountain Repository. However, because it is reasonable to assume that low-level radioactive waste shipments to the Nevada Test Site could continue and occur coincidentally with shipments to the Yucca Mountain Repository, Section 8.4 analyzes the potential for cumulative impacts from the construction and operation of these two intermodal transfer stations as well as a privately owned intermodal transfer station described in the following section.

Timbisha Shoshone Reservation

The Secretary of the Interior issued a draft report to Congress (DIRS 103470-Timbisha Shoshone and DOI 1999, all) describing a plan to establish a discontiguous reservation for people of the Timbisha Shoshone Tribe in portions of the Mojave Desert in eastern California and southwestern Nevada. On

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November 1, 2000, the President signed Bill S.2102 (Public Law 106-423) to provide a permanent land base for the Timbisha Shoshone Tribe within its ancestral homeland.

The National Park Service of the U.S. Department of the Interior prepared a Legislative EIS (DIRS 154121-DOI 2000, all), which describes the environmental impacts of this action. The EIS analyzes the potential transfer of almost 32 square kilometers (7,800 acres) in five noncontiguous parcels in portions of the Mojave Desert in eastern California and southwestern Nevada, as follows:

- Approximately 1.3 square kilometers (314 acres) in Furnace Creek, Death Valley National Park, California
- Approximately 4 square kilometers (1,000 acres) in Death Valley Junction, California
- Approximately 11 square kilometers (2,800 acres) in Scottys Junction, Nevada
- Approximately 2.6 square kilometers (640 acres) in Centennial, California
- Approximately 12 square kilometers (3,000 acres) in Lida, Nevada

Of these five parcels, the first three are in whole or in part within the 80-kilometer (50-mile) radius of the proposed repository. In addition to these five parcels, the Law authorizes the Secretary of the Interior to purchase two additional parcels of land with water rights as follows:

- Approximately 0.49 square kilometer (120 acres) at the Indian Rancheria Site, California
- Approximately 9.5 square kilometers (2,340 acres) at Lida Ranch, Nevada

In addition, Public Law 106-423 prescribes Federal water rights for these parcels of land and describes partnerships between the National Park Service and the Timbisha Shoshone Tribe that will provide economic and cultural opportunities for the Tribe while preserving the resources in the area. As described in the Legislative EIS (DIRS 154121-DOI 2000, all), activities on the parcels of land would not differ greatly from their historic uses. Modern housing with the associated infrastructure could be constructed at the Furnace Creek site, but would be limited by law to conserve and protect resources. Commercial development is permitted at several of the sites, but would have to be consistent with existing designations and uses of the land. The future development could cause potential transportation impacts, but the lack of information on specific plans precludes a detailed analysis at this time.

Because of the proximity of some of the parcels to the proposed repository and to some of the transportation corridors, there are potential cumulative impacts between their use and the proposed repository with regard to land use, regional water use, and transportation impacts. Therefore, DOE considered this action in its analysis of cumulative impacts in this chapter. As discussed in Chapter 6, the parcel near Scottys Junction (shown in Figure 8-1), if inhabited, could be affected if a rail corridor was used in the future.

8.1.2.3 Non-Federal and Private Actions

The following paragraphs describe reasonably foreseeable future actions of non-Federal and private agencies or individuals that could result in cumulative impacts. This EIS considers the Cortez Pipeline Gold Deposit projects described below to be private actions even though they require the approval of the Bureau of Land Management.

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Cortez Pipeline Gold Deposit Projects

The Cortez Gold Mine Pipeline Project is near the potential branch rail line in the Carlin Corridor in Nevada (see Chapter 6, Section 6.3.2.2.2). Cortez Gold Mine, Inc., operates the Pipeline Project mine and processing facility; the environmental impacts of the existing mining operation are discussed in the *Cortez Pipeline Gold Deposit: Final Environmental Impact Statement* (DIRS 103078-BLM 1996, all). The Pipeline Infiltration Project (which was approved in March 1999) would expand the Pipeline Project area to add more land for the construction and operation of infiltration ponds to support the existing mine (DIRS 103081-BLM 1999, all). The Bureau of Land Management published the *South Pipeline Project Final Environmental Impact Statement* (DIRS 155530-BLM 2000, all) in which the proposed action was to "develop the South Pipeline ore deposit and construct associated facilities to continue to extract gold from the mined ore within the existing Project Area." Based on an analysis of the general area potentially affected by the Cortez Gold Mine Project, there could be cumulative land-use and ownership impacts with the proposed Carlin rail corridor (see Figure 8-2). The Bureau issued the Record of Decision for the EIS on June 27, 2000 (DIRS 155095-BLM 2000, all). On July 31, 2000, the Western Mining Action Project (representing Great Basin Mine Watch, Western Shoshone Defense Project, and Mineral Policy Center) filed an Appeal and Request for Stay (DIRS 155531-BLM 2001, all); however, the stay request was denied in January 2001.

Apex Bulk Commodities Intermodal Transfer Station

Apex Bulk Commodities is negotiating with BHP Copper of Ely, Nevada, to build an intermodal transfer station at Caliente near the potential intermodal transfer station site for shipping spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository. Apex anticipates one diesel truck per hour carrying 40 tons of copper concentrate, 24 hours per day, for 15 years. An improved access road and about 4,200 meters (14,000 feet) of new rail would be constructed. The transfer facility would be housed in a building 90 by 30 meters (300 by 100 feet) designed to retain dust, water, and spills generated during the transfer process. Air emission particulates would be collected in two baghouses. Apex would also need a truck maintenance facility, which would be in a building 30 by 18 meters (100 by 60 feet). An above-ground storage tank for about 45,000 liters (12,000 gallons) of diesel fuel is also planned. Apex estimates 25 new jobs for Caliente and an annual payroll of $800,000 (DIRS 103225-DOE 1998, p. 5-5).

Although a start date for Apex copper concentration intermodal transfer station and truck transportation operations is unknown, Section 8.4 analyzes the potential for cumulative impacts from the construction and operation of that station, assuming these activities would coincide with impacts from the Nevada Test Site low-level radioactive waste intermodal transfer station and the intermodal transfer station for shipments to the proposed Yucca Mountain Repository.

Shared Use of a DOE Branch Rail Line

If DOE built a branch rail line to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository, it could share the use of this line with others. A branch rail line in the Carlin corridor could provide transportation service options for mine operators in the central mountain valleys of Nevada and could provide freight service options for southwestern Nevada communities such as Tonopah, Beatty, Goldfield, and Pahrump. A branch rail line in the Caliente corridor could serve those communities plus Warm Springs, along with mine operators in the interior of Nevada. A branch rail line in the Valley Modified or Jean corridors would provide freight service access to farms, industries, and businesses in the Amargosa Valley and Pahrump communities. A Valley Modified branch line would also provide rail service to the Indian Springs community. Any of the potential branch rail lines to the Yucca Mountain site (see Chapter 6, Figure 6-14) would provide rail access to the Nevada Test Site. The shared use of a branch rail line would have positive economic benefits, but could produce cumulative impacts due to increased operations and traffic.

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Private Fuel Storage at Skull Valley

In June 2000, the Nuclear Regulatory Commission published the *Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah* (DIRS 152001-NRC 2000, all). That EIS evaluates the environmental impacts of constructing and operating a facility for the interim storage of commercial spent nuclear fuel.

The storage site would be on the reservation of the Skull Valley Band of Goshute Indians in Skull Valley in Tooele County, Utah. The facility would occupy approximately 3.3 square kilometers (820 acres) and would involve construction of a 52-kilometer (32-mile) rail line on public land administered by the Bureau of Land Management from Skunk Ridge (near Low, Utah) to the reservation.

The facility would be constructed and operated by Private Fuel Storage, LLC, a limited liability company comprised of eight U.S. power utilities.

The storage site would be designed to store up to 40,000 metric tons of heavy metal (MTHM) of commercial spent nuclear fuel, which is sufficient to store all the spent nuclear fuel from the Private Fuel Storage member utilities as well as additional fuel from non-member utilities. The fuel would be stored in above-ground concrete vault structures that would provide structural integrity and radiation shielding. The proposed facility would be licensed by the Nuclear Regulatory Commission to operate for as long as 20 years, at which time the Commission could renew the license.

The facility would be used as an interim storage facility until a geologic repository was available for disposal of the spent nuclear fuel. Therefore, the actions considered in the Nuclear Regulatory Commission EIS could have cumulative impacts with those contemplated in the Yucca Mountain EIS by affecting the transportation routes through which material would arrive at the proposed repository. However, because of the distance of the storage facility from the Yucca Mountain site, DOE does not expect cumulative impacts between the proposed operation of the facility and the Proposed Action for this EIS.

Section 8.4 discusses estimated impacts from transportation of material to the Private Fuel Storage facility.

Owl Creek Energy Project

The Owl Creek Energy Project (DIRS 155595-Stuart and Anderson 1999, all) is a potential interim storage project for commercial spent nuclear fuel that would be developed in the State of Wyoming. The location for the project is near the Town of Shoshoni, Wyoming, and consists of about 11 square kilometers (2,700 acres) of privately owned land with access to rail and nearby roads. A private company is pursuing the project, which would be temporary, with a projected life of 40 years.

The Owl Creek Energy Project would involve the storage of spent nuclear fuel using dry storage techniques in specially designed facilities. However, the project is still in its infancy; no license application has been submitted to the Nuclear Regulatory Commission. Further, the potential impacts of the facility are unknown at present. Therefore, DOE has not attempted to quantify potential impacts at this time, but believes it would be unlikely that the operational impacts would be markedly different from those expected for the Private Fuel Storage Facility in Tooele County, Utah (described above).

Moapa Paiute Energy Center

In March 2001, the Bureau of Indian Affairs issued the *Moapa Paiute Energy Center Draft Environmental Impact Statement* (DIRS 155979-PBS&J 2001, all). Calpine Corporation proposes to construct the Moapa Paiute Energy Center on 0.26 square kilometer (65 acres) of land leased from the Moapa River Paiute Reservation approximately 12 kilometers (45 miles) northeast of Las Vegas. The plant would consist of a nominal 760-megawatt baseload natural-gas-fired, combined-cycle power unit with peak capacity to approximately 1,100 megawatts. The land disturbance would consist of as much as 0.88 square kilometer (218 acres) of reservation land and as much as 0.33 square kilometer (82 acres) of off-reservation lands. Transmission lines would follow an existing Bureau of Land Management utility corridor that passes through the reservation, requiring no change in land use. The lines would pass approximately 19 kilometers (12 miles) to the southwest to the existing Nevada Power Company Harry Allen Substation. The natural gas supply system to the facility would consist of approximately 1,220 meters (4,000 feet) of pipeline and a pumping station. The natural gas line and the pump station would require approximately 0.004 square kilometer (5.5 acres). The Bureau of Land Management would be responsible for rights-of-way for construction, operation, and termination for the facilities in the utility right-of-way on the reservation.

Because the Energy Center would be some distance from the proposed repository, there is minimal potential for direct cumulative impacts with repository operation. Groundwater management practices would minimize depletion of groundwater resources. Air emissions would be minimized, and there would be essentially no potential for overlap of the plumes from the repository and the Energy Center.

Southern Nevada Public Land Management Act

The Southern Nevada Public Land Management Act (Public Law 105-263) authorizes the Bureau of Land Management to sell some public lands in the Las Vegas Valley to promote responsible and orderly development.

The law specifies that money generated by these land sales will remain in Nevada. This money will provide funding for a variety of land management activities emphasizing recreation sites, such as the following:

- Acquisition of environmentally sensitive land in Nevada, with priority given to lands in Clark County
- Capital improvements at the Lake Mead National Recreation Area, the Desert National Wildlife Refuge, the Red Rock Canyon National Conservation Area, and other areas administered by the Bureau of Land Management in Clark County, and the Spring Mountains National Recreation Area (subject to an annual limitation)
- Development of a multispecies habitat conservation plan in Clark County, Nevada
- Development of parks, trails, and natural areas in Clark County

The Act included approximately 110 square kilometers (27,000 acres) of land for sale (Public Law 105-263). As of April 2001, the Bureau of Land Management had conveyed about 17 square kilometers (4,200 acres) to private and commercial entities. In December 2000, the Bureau published its “Round 2 Preliminary Recommendation” in which it recommended the acquisition of more than 23 square kilometers (5,800 acres) of land throughout Nevada that is privately or commercially owned to be distributed among the Bureau, the National Park Service, and the Forest Service (DIRS 155597-BLM 2000, all).

This action has potential land use cumulative impacts because some of the parcels conveyed or acquired by the Bureau of Land Management could be either within the 80-kilometer (50-mile) radius of the proposed repository or near potential transportation corridors, although DOE cannot predict which parcels might be affected or the timing of such conveyances.

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Ivanpah Valley Airport

On October 27, 2000, the President signed the Ivanpah Valley Airport Public Lands Transfer Act (Public Law 106-362) to transfer Federal lands in Ivanpah Valley, Nevada, to Clark County. The land to be transferred, which is part of the Mojave National Preserve, would be used for construction of a general aviation airport at Jean, Nevada.

The passage of the Ivanpah Valley Airport Public Lands Transfer Act does not automatically transfer the lands. Under provisions of the bill, the U.S. Departments of the Interior and Transportation must complete an environmental impact statement before an actual transfer. As described in Chapter 6, the initiation of the Stateline option of the Jean Corridor for a potential branch rail line encroaches upon the land to be transferred. Therefore, this EIS evaluates the potential for cumulative impacts due to the land transfer.

Desert Space Station Science Museum

The Nevada Science and Technology Center is proposing to construct an 8,800-square-meter (95,000-square-foot) museum on 1.8 square kilometers (450 acres) of land in Amargosa Valley at the intersection of U.S. Highway 95 and State Route 373 (DIRS 148148-Williams and Levy 1999, p. 1). The land would be transferred from the Bureau of Land Management to Nye County, which in turn would lease the land to the Nevada Science and Technology Center (DIRS 155478-Dorsey 2001, all). As shown in Figure 8-2, this parcel of land is near the Nevada Test Site and is, thus, within the region of influence for the proposed repository.

Because detailed quantitative impact information is not available, DOE has not included a detailed analysis of this action other than to report the potential land use implications in Section 8.2.1.

8.2 Cumulative Short-Term Impacts in the Proposed Yucca Mountain Repository Region

This section describes short-term cumulative impacts during the construction, operation and monitoring, and closure of the repository in the regions of influence for the resources the repository could affect. DOE has organized the analysis of cumulative impacts by resource area. As necessary, the discussion of each resource area includes cumulative impacts from Inventory Module 1 or 2; from other Federal, non-Federal, and private actions; and from the combination of Inventory Modules 1 and 2 and other Federal, non-Federal, and private actions. Table 8-5 summarizes these impacts. The impacts listed for the Proposed Action in Table 8-5 include the combined effects of the potential repository and transportation activities.

There would be essentially no difference in the design and operation of the repository for Inventory Modules 1 and 2. As described in Appendix A, the radioactive inventory for Greater-Than-Class-C waste and for Special-Performance-Assessment-Required waste is much less than that for spent nuclear fuel and high-level radioactive waste. The subsurface emplacement of the material in Inventory Module 2, in comparison with the inventory for Module 1, would not greatly increase radiological impacts to workers or the public (DIRS 104523-CRWMS M&O 1999, p. 6-44). For the surface facilities, the number of workers and the radiological exposure levels would be the same for Inventory Modules 1 and 2 (DIRS 104508-CRWMS M&O 1999, Tables 6-1, 6-2, 6-4, and 6-5). Therefore, DOE did not perform separate analyses for Modules 1 and 2 to estimate the short-term impacts. This section identifies the short-term impacts as being for Modules 1 and 2, indicating that the impacts for the two modules would not differ greatly.

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Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 1 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Land use and ownership	Withdraw about 600 square kilometers (150,000 acres) of land already under Federal control by DOE, U.S. Air Force, and Bureau of Land Management. Public access to about 200 square kilometers (50,000 acres) of BLM public lands would be terminated. About 6.0 square kilometers (1,500 acres) of withdrawn land would be disturbed for the repository under the Proposed Action. As much as 20 square kilometers (4,900 acres) of land would be disturbed along transportation routes in Nevada, a portion of which would be in the Yucca Mountain region and could include the need for rights-of-way agreements or withdrawals.	Land withdrawal impacts would be the same as those for the Proposed Action. As much as 1 square kilometer (250 acres) of additional land would be disturbed, for a total of as much as 7.0 square kilometers (1,730 acres). Land use and ownership impacts from transportation would be the same as for the Proposed Action.	In addition to impacts for the Proposed Action, under current and reasonably foreseeable actions, 10,000 acres of federal land would be transferred for Indian reservations; 65 acres of reservation land would be used for commercial purposes; in excess of 38,000 acres of Federal land would be used for private and commercial purposes. There is the potential for over 5,800 acres of privately owned land to be acquired by the Federal Government. An intermodal transfer station could be constructed for shipping low-level radioactive waste within the Yucca Mountain region.	Withdraw about 600 square kilometers (150,000 acres) of land already under Federal control by DOE, U.S. Air Force, and Bureau of Land Management. Public access to about 200 square kilometers (50,000 acres) of BLM public lands would be terminated. As much as 27 square kilometers (1,100 acres) of withdrawn land would be disturbed for the repository and along transportation route. In addition to impacts for the Proposed Action, under current and reasonably foreseeable actions, 10,000 acres of federal land would be transferred for Indian reservations; 65 acres of reservation land would be used for commercial purposes; in excess of 38,000 acres of Federal land would be used for private and commercial purposes. There is the potential for over 5,800 acres of privately owned land to be acquired by the Federal Government.
Air Quality				
Nonradiological	Criteria pollutant [nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter ($PM_{10,}$ $PM_{2.5}$)] and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be less than 6 percent of applicable regulatory limits (see Tables 8-6, 8-7, and 8-8). Emissions associated with transportation in the proposed repository region would be low.	Criteria pollutant and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be less than 7 percent of applicable regulatory limits (see Tables 8-6, 8-7, and 8-8). Emissions associated with transportation in the proposed repository region would be low.	Nevada Test Site: Baseline monitoring shows that criteria pollutants at the Nevada Test Site and in the proposed repository region are well below National Ambient Air Quality Standards and would result in very small cumulative nonradiological air quality impacts. Emissions associated with the transportation of waste, people, and materials for Nevada Test Site activities in the repository region would be low.	Criteria pollutant and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be small fractions of applicable regulatory limits (generally less than 10 percent). Emissions associated with transportation in the repository region would be low.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 2 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Air Quality (continued)				
Radiological[b]	The maximally exposed individual in the public would receive an estimated annual radiation dose of 1.3 millirem or less (see Tables 8-10, 8-11, 8-12, and 8-13), primarily from naturally occurring radon.	The maximally exposed individual in the public would receive an estimated annual dose of 2.2 millirem or less, primarily from naturally occurring radon.	Nevada Test Site: Activity would continue to contribute extremely small increments to the risk to the general population and should not increase injury or mortality rates. As an example, the maximally exposed individual in the public would receive an estimated annual radiation dose of less than 0.15 millirem from past, present and reasonably foreseeable future activities.	The maximally exposed individual in the public would receive an annual radiation dose of 2.5 millirem or less, which is well below the 10 CFR 63.204 limit of 15 millirem from radioactive material releases from the repository and the Nevada Test Site.
Hydrology				
Surface water	Between 2.8 and 4.5 square kilometers (690 and 1,100 acres) of land would be newly disturbed and resulting impacts would likely be small and limited to the site. Impacts from construction and use of transportation capabilities (heavy-haul and rail) in the site vicinity and region would result in small impacts to surface water. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Additional transportation floodplain/wetlands assessments would be performed in the future as necessary.	Would be similar to impacts from the Proposed Action with an increase of as much as 1 square kilometer (250 acres) in new surface disturbance for a total of as much as 5.5 square kilometers (1,360 acres). Impacts from construction and use of transportation capabilities (heavy-haul and rail) would be small. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Transportation floodplain/wetlands assessments would be performed in the future as necessary.	No other actions were identified with potential cumulative surface-water impacts within the region of influence of repository construction, operation and monitoring, and closure. Transportation impacts would be small.	As much as 5.5 square kilometers (1,360 acres) of land would be newly disturbed and resulting impacts would likely be minor and limited to the site. Impacts from construction and use of transportation capabilities (heavy-haul and rail) in the site vicinity and region would result in small impacts to surface water. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Transportation floodplain/wetlands assessments would be performed in the future as necessary.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 3 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Hydrology (continued)				
Groundwater	Annual water demand would be between 230 and 290 acre-feet (during emplacement), and below the lowest estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet). Water use for the construction of a rail line could be as much as 710 acre-feet from multiple wells and hydrographic areas over 4 years.	Anticipated annual water demand (below Nevada State Engineer's ruling on perennial yield) could be slightly higher (ranging from 240 to 320 acre-feet) than that of the Proposed Action, and the highest demand, which would also occur when emplacement and development activities occurred together, would extend for an additional 14 years. Water use for transportation would be the same as that for the Proposed Action.	Nevada Test Site: Anticipated annual water demand from Nevada Test Site activities would be about 280 acre-feet, which is less than the estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet).	Combining the highest annual water demand of the repository of 320 acre-feet (during emplacement and development activities for the lower-temperature maximum spacing scenario with Modules 1 or 2) with annual water withdrawals from the Nevada Test Site of 280 acre-feet would result in a total of 600 acre-feet, which would slightly exceed the lowest estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet), but would not approach the highest estimate of perennial yield, which is 4,000 acre-feet. There is a potential for drawdown of the water level in nearby wells from water withdrawal. The combined peak annual water use of a repository under other operation options, even with Modules 1 or 2, with Nevada Test Site annual water use would result in a maximum peak cumulative use of about 560 acre-feet per year, which is below the lowest estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet). In addition, up to 710 acre-feet of water over 2.5 years would be used to construct a rail line in Nevada.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 4 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Biological resources and soils	Between 2.8 and 4.5 square kilometers (690 to 1,100 acres) of soil, habitat, and vegetation would be newly disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise and loss of individuals would occur. Wetland assessment concluded impacts would be small. Impacts from transportation would include the loss of 0 (legal-weight truck) to 20 square kilometers (4,900 acres) (rail) of habitat in Nevada. Impacts to the desert tortoise probably would occur if a rail line were constructed. Additional wetlands assessments would be performed in the future as necessary.	Inclusive of the Proposed Action, a total of as much as 5.5 square kilometers (1,360 acres) of soil, habitat, and vegetation would be disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise would occur. Wetland assessment concluded impacts would be small. Impacts from transportation would be the same as those under the Proposed Action. Additional wetlands assessments would be performed in the future as necessary.	No other actions were identified with potential cumulative biological resource or soil impacts within the region of influence of repository construction, operation and monitoring, and closure.	As much as 5.5 square kilometers (1,360 acres) of soil, habitat, and vegetation would be newly disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise and loss of individuals would occur. Impacts to potential jurisdictional wetlands would be very small and minimized. Impacts from transportation would include the loss of 0 (legal-weight truck) to 20 square kilometers (4,900 acres) (rail) of habitat in Nevada, a portion of which would be within the Yucca Mountain vicinity. Impacts to the desert tortoise and wetlands probably would occur if a rail line were constructed. Additional wetlands assessments would be performed in the future as necessary.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 5 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Cultural resources	Repository development would disturb about 2.8 to 4.5 square kilometers (690 to 1,100 acres). Direct and indirect impacts (damage to archaeological and historical sites or illicit collection of artifacts) would be mitigated per applicable regulations. In addition, as much as 20 square kilometers (4,900 acres) would be disturbed along transportation routes in Nevada. Native Americans view all impacts to be adverse and immune to mitigation.	Land disturbance for repository development would increase to a total of as much as 5.5 square kilometers (1,360 acres). Transportation impacts would be the same as those under the Proposed Action. Direct and indirect impacts and mitigations would be similar to the Proposed Action. Native Americans view all impacts to be adverse and immune to mitigation.	No other actions were identified with potential cumulative cultural resource impacts within the region of influence of repository construction, operation and monitoring, and closure. Native Americans view all impacts to be adverse and immune to mitigation.	Repository development would disturb as much as 5.5 square kilometers (1,360 acres). As much as 20 square kilometers (4,900 acres) would be disturbed if a rail line was constructed in Nevada. Direct and indirect impacts (damage to archaeological and historical sites or illicit collection of artifacts) would be mitigated per applicable regulations. Native Americans view all impacts to be adverse and immune to mitigation.
Socioeconomics	Estimated peak direct employment of 3,400 occurring in 2006 would result in less than a 1 percent increase in direct and indirect regional employment. Employment increases would range from less than 1 percent to approximately 5 percent (use of intermodal transfer station or rail line in Lincoln County, Nevada) of total employment by county.	Estimated peak direct employment would be the same as for the Proposed Action.	Nevada Test Site: Any employment increases would occur prior to construction of the repository and no cumulative impacts would be expected.	Estimated peak employment increase of about 3,400 occurring in 2006 would result in less than a 1-percent increase in direct and indirect regional employment (with as much as a 5-percent change in Lincoln County, Nevada if intermodal transfer station or rail line were located there).
Occupational and public health and safety[d]				
Nonradiological health impacts	2 to 3 fatalities[e] during construction, operation and monitoring, and closure. Exposures well below regulatory limits. Also, between 14 and 26 fatalities[e] from commuting, and transportation of material (repository and rail line construction material, as well as spent nuclear fuel and high-level radioactive waste).	4 or less fatalities[e] during construction, operation and monitoring, and closure. Exposures well below regulatory limits. Also, between 19 and 33 fatalities[e] from commuting, and transportation of material (repository and rail line construction material, as well as spent nuclear fuel and high-level radioactive waste).	No other actions were identified with potential cumulative industrial hazard impacts to repository workers.	23 to 37 fatalities[e] during construction, operation and monitoring, and closure (including transportation). Exposures well below regulatory limits.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 6 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Occupational and public health and safety (continued)[d]				
Radiological health impacts				
Workers	4 to 7 latent cancer fatalities[e] from repository construction, operation and monitoring, and closure. Up to 3 to 12 latent cancer fatalities[e] to workers from mostly rail and mostly truck, respectively.	5 to 8 latent cancer fatalities[e] from repository construction, operation and monitoring, and closure. Up to 7 to 24 latent cancer fatalities[e] to workers from mostly rail and mostly truck, respectively.	No other actions were identified with potential cumulative radiological health impacts to repository workers.	About 12 to 32 latent cancer fatalities[e] from repository construction, operation and monitoring, and closure (including transportation).
Public	Estimated doses would result in less than 1 latent cancer fatality to the public from repository construction, operation and monitoring, and closure. Up to 1 to 3 latent cancer fatalities[e] would result from transport by mostly rail and mostly truck, respectively.	Estimated doses would result in less than one latent cancer fatality to the public from repository construction, operation and monitoring, and closure. Impacts from transportation would be almost twice those from the Proposed Action.	Nevada Test Site: Estimated doses and associated health effects from the Nevada Test Site would be less than one latent cancer fatality.	About 2 to 5 latent cancer fatalities[e] from repository construction, operation and monitoring, and closure (including transportation); and Nevada Test Site activities.
Accidents	No latent cancer fatalities would be likely from the maximum reasonably foreseeable repository accident scenarios. Between 1 and 5 latent cancer fatalities would result from a maximum reasonably foreseeable transportation accident scenario that has less than 3 chances in 10 million of occurring.	The accident risk (probability of occurrence times consequence) is essentially the same as that for the Proposed Action. Impacts of a maximum reasonably foreseeable transportation accident scenario would be the same as those for the Proposed Action.	No other actions were identified with potential cumulative accident risk impacts.	No latent cancer fatalities would be likely from the maximum reasonably foreseeable repository accident scenarios. Between 1 and 5 latent cancer fatalities would result from a maximum reasonably foreseeable transportation accident scenario that has less than 3 chances in 10 million of occurring.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 7 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Noise	Impacts from construction, operation and monitoring, and closure of a repository would result in low noise impacts. Noise levels would be transient, less than 90 dBA[c]. New intermittent noise source if a rail line was used in Nevada, including in the Yucca Mountain region.	Same as the Proposed Action.	Future development of the Timbisha Shoshone Homeland parcel near Scottys Junction could result in residents or businesses being exposed to up to 90 dB of noise from the transportation route.	Impacts from construction, operation and monitoring, and closure of a repository would result in low noise impacts. Noise levels would be transient, less than 90 dBA[c]. New intermittent noise source if a rail line was used in Nevada, including in the Yucca Mountain.
Aesthetics	Placement of exhaust stacks on top of Yucca Mountain could possibly impact visual resources, since stacks would be visible for some distance. If the stacks were equipped with beacons, the visual effect would be more noticeable at night. Rail line construction would occur if rail was used in Nevada. Possible conflict with visual resource management goals for Jean rail corridor.	Same as the Proposed Action.	Disturbed areas are likely on former federal lands that are used for commercial and private purposes. Acquisition of private lands by the federal government could result in reduced aesthetics impacts and possible return of land to natural state.	Placement of exhaust stacks on top of Yucca Mountain could possibly impact visual resources, since stacks would be visible for some distance. If the stacks were equipped with beacons, the visual effect would be more noticeable at night. Rail line construction would occur if rail was used in Nevada. Possible conflict with visual resource management goals for Jean rail corridor. Disturbed areas are likely on former federal lands that are used for commercial and private purposes. Acquisition of private lands by the federal government could result in reduced aesthetics impacts and possible return of land to natural state.
Utilities, energy, materials, and site services	Peak electric power demand would require an upgrade to the electrical transmission and distribution system. Adverse impacts on energy and material supplies or to site services would be unlikely, including materials needed for transportation capabilities in the Yucca Mountain vicinity.	Peak electric power demand would require upgrade to the electrical transmission and distribution system. Although requirements for electricity, fossil fuels, concrete, steel, and copper would increase, adverse impacts to energy and material supplies or to site services would be unlikely, including materials needed for transportation capabilities in the Yucca Mountain vicinity.	Construction of other energy supply facilities, such as the Moapa Paiute Energy Center or the Alternative Energy Facility at the Nevada Test Site could provide additional electrical capacity for the region.	Peak electric power demand would require upgrade to the electrical transmission and distribution system. (See Chapter 4, Section 4.1.11.) Adverse impacts on energy and material supplies or to site services would be unlikely, including materials needed for transportation capabilities in the Yucca Mountain vicinity.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 8 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Waste management	Disposal of repository-generated low-level waste would require about 4 percent of the reserve capacity of the Nevada Test Site. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, existing landfills would need to be expanded.	Disposal of repository-generated low-level waste would require about 9 percent of the reserve capacity of the Nevada Test Site. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, the larger quantity of this waste would require even further landfill expansion at the Nevada Test Site.	Nevada Test Site: The total low-level radioactive waste disposal capacity of the Nevada Test Site is sufficient and would not be exceeded by the combined actions of repository development and selection of the Nevada Test Site as a regional disposal site for DOE-complex-wide low-level radioactive and mixed wastes.	The Nevada Test Site has sufficient capacity for low-level radioactive waste from all reasonably foreseeable future actions. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, existing landfills would need to be expanded.
Environmental justice	No disproportionately high and adverse impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on access to the proposed site.	No disproportionately high and adverse impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on access to the proposed site.	No other actions were identified with potential cumulative impacts within the region of influence of repository construction, operation and monitoring, and closure that would create environmental justice concerns. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on access to the proposed site.	No disproportionately high and adverse cumulative impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on access to the proposed site.

a. As described in Section 8.1.2.1, there would be essentially no difference in the design and operation of the repository for Inventory Module 1 or 2. Therefore, the analysis considered cumulative impacts from Inventory Module 2 to be the same as those from Inventory Module 1.

b. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public.

c. dBA = A-weighted decibels, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

d. Occupational and public health and safety impacts for the Proposed Action and Inventory Module 1 or 2 include both impacts from transportation activities in the repository region of influence as well as impacts estimated to occur nationally from transportation of spent nuclear fuel and high-level radioactive waste.

e. These ranges represent the maximum for each environmental resource area. Because the maximum could occur for different implementing alternatives in the various resource areas, simple addition of these summary level maximums could overstate the impacts due to mixing of incompatible alternatives.

DOE performed quantitative calculations for long-term impacts for both modules (see Section 8.3.1). The conclusion from these quantitative estimates was that the long-term impacts for Modules 1 and 2 would not differ greatly.

In estimating the potential impacts considered in this EIS, DOE consulted various documents, including resource plans, other National Environmental Policy Act documents, and technical documents. If appropriate, DOE has cited these documents in the discussion of each technical discipline.

Based on comments received during scoping and on the Draft EIS, DOE considered the Special Nevada Report from September 1991 (DIRS 153277-SAIC 1991, all) for inclusion as a source of technical information for the EIS. The Special Nevada Report, which was mandated by the Military Lands Withdrawal Act of 1986, contains a description of defense-related activities (as identified in 1991) along with estimates of potential impacts from those activities. However, the cumulative impacts analysis in this chapter considered the agencies that report represents—the Department of the Air Force, Department of the Navy, and Department of the Interior. Evaluations of the cumulative impacts of repository activities and other agency activities included review of a number of documents that are more current than the Special Nevada Report, including National Environmental Policy Act documents prepared by the Federal agencies listed throughout Section 8.1. Therefore, based on these more recent reports, DOE believes this report does not provide additional insight into projections of future impacts and, therefore, did not use it in its analysis of cumulative impacts.

8.2.1 LAND USE AND OWNERSHIP

The ownership, management, and use of the analyzed land withdrawal area described in Chapter 4, Section 4.1.1 for the Proposed Action would not change for Inventory Module 1 or 2. The amount of land required for surface facilities would increase somewhat for Module 1 or 2 because of the larger storage area for excavated rock and additional ventilation shafts for the larger required repository. This would have no substantial cumulative land-use or ownership impact.

To identify and quantify cumulative impacts for land use, DOE used a twofold approach. Actions that occurred within a 50-mile (80-kilometer) radius of the repository were reviewed for potential contributions to land use impacts. Second, actions that could affect transportation corridors were reviewed for their potential land use impacts. This second group of impacts is discussed in Section 8.4.2.1 (see Table 8-4).

Section 8.1 lists several actions that have the potential for land use impacts. DOE reviewed those actions to identify land areas that could be affected and has quantified, where possible, the amount of land that is subject to new uses. DOE identified how the land use would be converted (for example, undisturbed federal land to commercial use) and any restrictions that might affect the length of time the land would be used.

As discussed in Chapter 3, Section 3.1.1.1, the Federal Government manages approximately 240,000 square kilometers of land in Nevada, approximately 190,000 square kilometers of which are managed by BLM and available for public use. The land transfer/usage indicated in Table 8-6 represents approximately 340 square kilometers of additional land that is currently scheduled for removal from public use. In addition approximately 430 square kilometers would require removal from public use as the result of the potential development of a repository and transportation corridor. The total land removed from public use would represent less than 0.5 percent of BLM land and approximately 0.3 percent of the total Federal lands of Nevada. The largest change in land use is associated with the Southern Nevada Public Land Management Act. Although the Bureau of Land Management could convey as much as 110 square kilometers (27,000 acres) to private and commercial use, only about 17 square kilometers (4,200 acres) had been transferred as of April 30, 2001. As stipulated by the Act,

Table 8-6. Potential cumulative land use impacts for activities in or near the region of influence.[a]

Action	Land use conversion[b]	Ownership change	Land use restrictions
Moapa Paiute Energy Center[c]	Powerplant construction/ operation on 0.26 square kilometers of Reservation land.	Moapa Band of Paiute Indians to Calpine Corporation – powerplants footprint. Reservation to BLM for management of new natural gas pipeline	25-year lease with 20-year renewal
Ivanpah Cargo Airport[d]	Recreation and mining to airport and industrial development. Approximately 27 square kilometers, 8.1 square kilometers of which is for airport alone.	BLM to Clark County for public/private development	None
Timbisha Shoshone Reservation[e]	Grazing, recreation, mining, wildlife management to Tribal use (economic development, historic/cultural use, special use). Approximately 40 square kilometers.	NPS, BLM, and private lands to reservation/BIA	None
Cortez Mine[f]	Grazing, recreation, mining to mining 18 square kilometers.	BLM lease to Cortez Gold Mine	10 years
NTS Energy Generation Facility (Wind Farm)[g]	DOE land withdrawn for NTS to commercial use–4.9 square kilometers.	NTS subeasement to MNS through NTSDC	20 year generation period
Southern Nevada Public Land Management Act[h,i]	BLM general use to private/ commercial development and private/commercial land to public land. • Potential of 110 square kilometers to be transferred • 17 square kilometers conveyed as of April 30, 2001 • More than 23 square kilometers recommended by BLM to be acquired	• BLM to private/commercial • Private/commercial to BLM, NFS, NPS	None
Desert Space Station Science Museum[j]	BLM general use to commercial use (1.8 square kilometers).	BLM to Nye County	Land leased from Nye County to Nevada Science and Technology Center
Total land use impacts			
Federal land to Indian Reservations:	40 square kilometers		
Federal land to private and commercial use:	154+ square kilometers		
Private to Federal land:	25+ square kilometers (proposed as of December 2000)		

a. BLM = Bureau of Land Management; NTS = Nevada Test Site; NTSDC = NTS Development Corporation; MNS = M&N Wind Power Inc. and Siemans; NPS = National Park Service; BIA = Bureau of Indian Affairs.
b. To convert square kilometers to acres, multiply by 247.1.
c. Source: DIRS 155979-PBS&J (2001, pp. xi and xiii to xviii).
d. Source: Ivanpah Valley Public Lands Transfer Act (Public Law 106-362, 114 Stat. 1404).
e. Source: DIRS 154121-DOI (2000, Section 2.2).
f. Source: DIRS 155095-BLM (2000, pp. 1 to 13).
g. Source: DIRS 154545-DOE (2001, pp. 3-1 to 3-9).
h. Source: *Southern Nevada Public Land Management Act of 1998* (Public Law 105-263, 112 Stat. 2343).
i. Source: DIRS 155597-BLM (2000, all).
j. Source: DIRS 148148-Williams and Levy (1999, p. 1).

the Bureau has recommended acquiring about 23 square kilometers (5,800 acres) of environmentally sensitive lands throughout the State of Nevada that would be transferred from commercial and private use to general Bureau use.

Several land use conversions could result in commercial or private use of Federal lands. In addition to those lands transferred under the Southern Nevada Public Land Management Act, lands would be leased or transferred for the Ivanpah Cargo Airport, the Moapa Paiute Energy Center, the Cortez Mine, and the Desert Space Station Science Museum. These changes in land use would permit orderly development of public lands.

The projects that would occur on the Nevada Test Site and the Nellis Air Force Range would result in no net change in land use because the lands are already removed from the public use and are designated for development.

Some of the lands that would be transferred to the Timbisha Shoshone Nation could have some associated commercial use; however, this use would be consistent with the designations for the areas, and developments would be restricted to maintain the natural resources of the land.

In addition to the cumulative changes to land use and ownership, DOE considered potential conflicts with plans and policies issued by various government entities in the vicinity of the proposed Yucca Mountain Repository. In particular, DOE reviewed a number of documents issued by or in conjunction with Nye County and communities in Nye County. In general, the local governments have expressed goals that would minimize the conversion of private lands to public use. At this time DOE is not aware of any direct operational conflicts between the proposed repository and Nye County planning efforts because the Department does not foresee a need to expand the withdrawal area or for the conversion of private lands in the vicinity of the repository. Transportation-related issues are discussed in Section 8.4.2.1.

8.2.2 AIR QUALITY

8.2.2.1 Inventory Module 1 or 2 Impacts

This section addresses potential nonradiological and radiological cumulative impacts to air quality from emplacement in a repository at Yucca Mountain of the additional quantities of spent nuclear fuel and high-level radioactive waste above those evaluated for the Proposed Action, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste (that is, Inventory Modules 1 and 2). It compares potential nonradiological and radiological cumulative impacts to applicable regulatory limits, including the new U.S. Environmental Protection Agency National Ambient Air Quality Standard for particulate matter with a diameter of less than 2.5 micrometers. Chapter 3, Section 3.1.2.1, discusses the current status of this standard. Sources of nonradiological air pollutants at the proposed repository could include fugitive dust emissions from land disturbances, excavated rock handling, and concrete batch plant operations and emissions from fossil-fuel consumption.

8.2.2.1.1 *Nonradiological Air Quality*

The construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository for Inventory Module 1 or 2 would result in increased releases of criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter) and cristobalite as described in the following sections. The types of activities producing these releases would be the same as those described for the Proposed Action (see Chapter 4, Section 4.1.2).

Construction. The repository construction phase for Inventory Module 1 or 2 would produce the same levels of gaseous pollutants and cristobalite but slightly higher air concentrations of particulate matter, as listed in Table 8-7. The air concentrations would still be small fractions of the applicable regulatory limits.

Table 8-7. Estimated construction phase concentrations of criteria pollutants and cristobalite (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration[c,d,e] Higher-temperature	Maximum concentration[c,d,e] Lower-temperature	Percent of regulatory limit[e] Higher-temperature	Percent of regulatory limit[e] Lower-temperature
			Proposed Action			
Nitrogen dioxide	Annual	100	0.40	0.41 - 0.42	0.41	0.41 - 0.42
Sulfur dioxide	Annual	80	0.10	0.10	0.13	0.13
	24-hour	365	1.3	1.3	0.36	0.36
	3-hour	1,300	8.5	8.6 - 8.7	0.66	0.66 - 0.67
Carbon monoxide[f]	8-hour	10,000	4.2	4.3 - 4.4	0.041	0.042 - 0.043
	1-hour	40,000	29	29 - 30	0.072	0.073 - 0.075
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.69	0.74 - 0.94	1.4	1.5 - 1.9
	24-hour	150 (65)	6.5	7.0 - 8.4	4.3	4.7 - 5.6
Cristobalite	Annual[g]	10[g]	0.018	0.017 - 0.018	0.18	0.17 - 0.18
			Inventory Module 1 or 2			
Nitrogen dioxide	Annual	100	0.40	0.41 - 0.42	0.40	0.41 - 0.42
Sulfur dioxide	Annual	80	0.10	0.10	0.13	0.13
	24-hour	365	1.3	1.3	0.36	0.36
	3-hour	1,300	8.5	8.6 - 8.7	0.66	0.66 - 0.67
Carbon monoxide	8-hour	10,000	4.2	4.3 - 4.4	0.041	0.043
	1-hour	40,000	29	29 - 30	0.072	0.073 - 0.075
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.81	0.85 - 1.1	1.6	1.7 - 2.1
	24-hour	150 (65)	7.1	7.4 - 8.9	4.7	4.9 - 5.8
Cristobalite	Annual[g]	10[g]	0.018	0.017 - 0.018	0.18	0.17-0.18

a. Source: Appendix G, Section G.1.4.
b. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
c. Sum of highest concentrations at the accessible land withdrawal boundary, regardless of direction.
d. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.4.
e. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
f. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
g. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Operation and Monitoring. Table 8-8 lists estimated air quality impacts from criteria pollutants and cristobalite for Inventory Module 1 or 2. The concentrations in this table are for the period of continuing surface and subsurface development and emplacement activities. During the subsequent monitoring and maintenance activities these concentrations would decrease considerably. All concentrations are comparable to those produced under the Proposed Action. All concentrations would be small fractions of the applicable regulatory limits for Module 1 or 2. Because the development of the emplacement drifts for Module 1 or 2 would take additional time compared to the Proposed Action, these releases of criteria pollutants would occur over a longer period than those from the Proposed Action. In general, the values in Table 8-8 for operation and monitoring are smaller than the values in Table 8-7 for construction because there would be more land surface disturbance during construction.

Closure. Continuing the closure of the repository for either Inventory Module 1 or 2 would produce comparable, but slightly lower, concentrations of gaseous pollutants, particulate matter, and cristobalite than those estimated for the Proposed Action. The concentrations would still be small fractions of the applicable regulatory limits (see Table 8-9). With Inventory Module 1 or 2, the amount of backfill required to close the ramps, main tunnels, and ventilation shafts would be larger than that for the Proposed Action, and the size of the excavated rock pile to reclaim would be larger. However, the

Table 8-8. Estimated operation and monitoring phase concentrations of criteria pollutants and cristobalite (micrograms per cubic meter).[a]

			Proposed Action			
			Maximum concentration[c,d,e]		Percent of regulatory limit[e]	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.28	0.28 - 0.31	0.28	0.29 - 0.32
Sulfur dioxide	Annual	80	0.089	0.089 - 0.092	0.11	0.11 - 0.12
	24-hour	365	1.2	1.2	0.33	0.34
	3-hour	1,300	7.8	7.9 - 8.0	0.60	0.61 - 0.62
Carbon monoxide	8-hour	10,000	2.7	2.7 - 3.0	0.026	0.027 - 0.029
	1-hour	40,000	19	19 - 21	0.048	0.049 - 0.052
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.080	0.10 - 0.19	0.16	0.20 - 0.39
	24-hour	150 (65)	0.97	1.3 - 2.3	0.65	0.87 - 1.6
Cristobalite	Annual[g]	10[g]	0.0093	0.009 - 0.017	0.093	0.091 - 0.17
			Inventory Module 1 or 2			
Nitrogen dioxide	Annual	100	0.28	0.29 - 0.32	0.28	0.29 - 0.32
Sulfur dioxide	Annual	80	0.089	0.090 - 0.093	0.11	0.12
	24-hour	365	1.2	1.2 - 1.3	0.34	0.34
	3-hour	1,300	7.9	7.9 - 8.1	0.60	0.61 - 0.62
Carbon monoxide	8-hour	10,000	2.6	2.7 - 2.9	0.026	0.026 - 0.029
	1-hour	40,000	19	19 - 21	0.047	0.048 - 0.052
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.18	0.18 - 0.23	0.37	0.37 - 0.46
	24-hour	150 (65)	2.6	2.6 - 3.0	1.7	1.7 - 2.0
Cristobalite	Annual[g]	10[g]	0.011	0.010 - 0.016	0.11	0.10 - 0.16

a. Source: Appendix G, Section G.1.5.
b. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
c. Sum of highest concentrations at accessible land withdrawal boundary, regardless of direction.
d. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.5.
e. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
f. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
g. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

duration of the closure period for Inventory Module 1 or 2 would increase over that of the Proposed Action, resulting in minor changes in the air concentrations between the Proposed Action and Inventory Module 1 or 2.

8.2.2.1.2 *Radiological Air Quality*

Inventory Module 1 or 2 would require more subsurface excavation and a longer closure phase leading to increased radon releases compared to the Proposed Action. The increased quantity of spent nuclear fuel that repository facilities would receive and package would also result in additional releases of krypton-85 from failed spent nuclear fuel cladding but, as for the Proposed Action, naturally occurring radon-222 and its radioactive decay products would still be the dominant dose contributors.

The following paragraphs discuss the estimated radiological air quality impacts in terms of the potential radiation dose to members of the public and workers for the construction, operation and monitoring, and closure phases of Inventory Module 1 or 2. For these estimates, workers exposed through the air pathway would be noninvolved workers.

Construction. Table 8-10 lists estimated doses to members of the public and workers for the construction phase. These values resulting from radon releases during the 5-year construction phase

Table 8-9. Estimated closure phase concentrations of criteria pollutants and cristobalite (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Proposed Action: Maximum concentration[c,d,e] Higher-temperature	Lower-temperature	Percent of regulatory limit[d] Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.54	0.54	0.54	0.54 - 0.55
Sulfur dioxide	Annual	80	0.11	0.11	0.15	0.15
	24-hour	365	1.4	1.4	0.38	0.38
	3-hour	1,300	9.3	9.3	0.71	0.71 - 0.72
Carbon monoxide	8-hour	10,000	4.7	4.7	0.045	0.045 - 0.046
	1-hour	40,000	31	31	0.078	0.078
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.38	0.34 - 0.37	0.76	0.67 - 0.73
	24-hour	150 (65)	5.5	5.2 - 5.4	3.6	3.4 - 3.6
Cristobalite	Annual[g]	10[g]	0.012	0.0089 - 0.0095	0.12	0.089 - 0.098
			Inventory Module 1 or 2			
Nitrogen dioxide	Annual	100	0.51	0.48 - 0.49	0.52	0.49
Sulfur dioxide	Annual	80	0.11	0.11	0.14	0.14
	24-hour	365	1.4	1.4	0.38	0.37
	3-hour	1,300	9.1	9.0	0.70	0.69
Carbon monoxide	8-hour	10,000	4.4	4.2 - 4.3	0.043	0.041 - 0.042
	1-hour	40,000	30	28 - 29	0.075	0.071 - 0.072
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.40	0.32 - 0.35	0.079	0.65 - 0.69
	24-hour	150 (65)	5.6	5.1 - 5.2	3.7	3.4 - 3.5
Cristobalite	Annual[g]	10[g]	0.013	0.010 - 0.013	0.13	0.10 - 0.13

a. Source: Appendix G, Section G.1.6.
b. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
c. Sum of highest concentrations at accessible land withdrawal boundary, regardless of direction.
d. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.6.
e. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
f. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
g. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

would be similar to those for the Proposed Action because the subsurface volume excavated would be about the same.

Operation and Monitoring. The doses from krypton-85 from receipt and packaging activities during operation and monitoring would be very low. Dose to the public would be only a fraction (0.00003 or less) of the dose from naturally occurring radon-222 and its radioactive decay products, as discussed below. Similarly, the dose to Yucca Mountain workers from krypton-85 would be a fraction (0.00001 or less) of the dose to those workers from radon-222. The annual dose from krypton-85 would be the same as that for the Proposed Action, but would occur for 38 years of spent nuclear fuel handling activities rather than 24 years.

Table 8-11 and Table 8-12 list doses to individuals and populations for operation and monitoring, respectively. In all cases, naturally occurring radon-222 would be the dominant contributor to the doses, which would increase because of the larger repository required for Inventory Module 1 or 2. Average annual doses would be higher to members of the public and higher to noninvolved workers during the 38 years of development and emplacement activities when the South Portal would be open and used for exhaust ventilation. The analysis estimated collective doses for public and worker populations for the 100 to 338 years for operation and monitoring, including the 38 years of development and emplacement activities and 62 to 300 years of monitoring and maintenance activities. The dose to the maximally exposed member of the public is for 38 years of operations and 32 years of monitoring (that is, a 70-year

Table 8-10. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during initial construction period.[a,b,c]

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual	Total	Maximum annual
	Proposed Action			
Dose to public				
Offsite MEI[d] (millirem)	1.7	0.43	1.7 - 2.0	0.43 - 0.53
80-kilometer population[e] (person-rem)	33	8.4	33 - 40	8.4 - 10
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[f] (millirem)	7.5	2.0	7.5 - 9.0	1.9 - 2.3
Yucca Mountain noninvolved worker population[g] (person-rem)	0.41	0.10	0.41 - 0.48	0.10 - 0.13
Nevada Test Site noninvolved worker population[h] (person-rem)	0.0013	0.00032	0.0013 - 0.0015	0.00032 - 0.00039
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	1.7	0.43	2.0	0.52 - 0.53
80-kilometer population (person-rem)	33	8.4	39 - 40	10
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker (millirem)	7.5	2.0	8.8 - 9.0	2.3
Yucca Mountain noninvolved worker population (person-rem)	0.41	0.10	0.47 - 0.49	0.12 - 0.13
Nevada Test Site noninvolved worker population (person-rem)	0.0013	0.00032	0.0015	0.00038 - 0.00039

a. Source: Appendix G, Section G.2.
b. Numbers are rounded to two significant figures.
c. Annual values are for the maximum year during the construction phase.
d. MEI = maximally exposed individual; public MEI location would be at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker would be in the South Portal Development Area.
g. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
h. DOE workers at the Nevada Test Site [about 6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Table 8-11. Estimated radiation doses to maximally exposed individuals and populations during operations activities.[a,b,c,d]

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual	Total	Maximum annual
	Proposed Action			
Dose to public				
Offsite MEI[e] (millirem)	12	0.73	17 - 43	1.0 - 1.3
80-kilometer population[f] (person-rem)	230	14	320 - 830	20 - 26
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[g] (millirem)	30	2.0	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker population[h] (person-rem)	1.2	0.081	1.8 - 1.9	0.12 - 0.13
Nevada Test Site noninvolved worker population[i] (person-rem)	0.011	0.00063	0.015 - 0.043	0.00090 - 0.0012
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	22	0.94	31 - 66	1.3 - 2.2
80-kilometer population (person-rem)	430	18	600 - 1,300	26 - 42
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker (millirem)	45	2.0	62 - 95	2.8 - 4.6
Yucca Mountain noninvolved worker population (person-rem)	1.8	0.081	2.5 - 4.1	0.11 - 0.2
Nevada Test Site noninvolved worker population (person-rem)	0.02	0.00085	0.028 - 0.063	0.0012 - 0.002

a. Source: Appendix G, Section G.2.
b. Numbers are rounded to two significant figures.
c. For Inventory Module 1 or 2, the operation and monitoring phase would last 100 years for the higher-temperature operating mode and 163 to 338 years for the lower-temperature operating mode.
d. Maximum annual dose occurs during the last year of development, when repository would be largest and South Portal would still be used for exhaust ventilation.
e. MEI = maximally exposed and individual; at the southern boundary of the land withdrawal area.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
g. Maximally exposed noninvolved worker would be in the South Portal Development Area.
h. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
i. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

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Table 8-12. Estimated radiation doses to maximally exposed individuals and populations during monitoring activities.[a,b,c,d]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual	Total	Maximum annual
	Proposed Action			
Dose to public				
Offsite MEI[e] (millirem)	29	0.41	30 - 62	0.59 - 0.89
80-kilometer population[f] (person-rem)	600	8	1,500 - 3,500	11 - 17
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[g] (millirem)	0.096	0.0019	0.16 - 0.33	0.0011 - 0.0067
Yucca Mountain noninvolved worker population[h] (person-rem)	0.0091	0.0013	0.0031 - 0.05	0.000034 - 0.0057
Nevada Test Site noninvolved worker population[i] (person-rem)	0.033	0.00044	0.083 - 0.019	0.00021 - 0.00094
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	39	0.62	20 - 100	0.29 - 1.4
80-kilometer population (person-rem)	740	12	2,200 - 5,400	5.6 - 28
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker (millirem)	0.22	0.0043	0.33 - 0.54	0.0022 - 0.011
Yucca Mountain noninvolved worker population (person-rem)	0.025	0.0044	0.067 - 0.1	0.000075 - 0.0091
Nevada Test Site noninvolved worker population (person-rem)	0.041	0.00066	0.12 - 0.3	0.00031 - 0.0015

a. Source: Appendix G, Section G.2.
b. Numbers are rounded to two significant figures.
c, For Inventory Module 1 or 2, the operation and monitoring phase would last 100 years for the higher-temperature operating mode and 163 to 338 years for the lower-temperature operating mode.
d. Maximum annual dose occurs during the last year of development, when repository would be largest and South Portal would still be used for exhaust ventilation.
e. MEI = maximally exposed individual; at the southern boundary of the land withdrawal area.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
g. Maximally exposed noninvolved worker would be in the South Portal Development Area.
h. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
i. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

lifetime). The dose to the maximally exposed noninvolved worker is for 50 years at the South Portal during development, emplacement, and monitoring activities.

Closure. Table 8-13 lists estimated doses to populations and maximally exposed individuals during the closure phase. Radiation doses would increase over those for the Proposed Action not only because of the larger excavated volume but also the longer time required for closure (12 to 23 years) in comparison to 10 to 17 years.

Summary. Based on the analysis of radiological air quality impacts from repository construction, operation and monitoring, and closure for Inventory Module 1 or 2, the estimated maximum annual dose to the maximally exposed individual member of the public would be 0.99 millirem for the lower-temperature operating mode during development and emplacement activities in the operation and monitoring phase. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 6.6 percent of this standard. The radiation dose is 0.3 percent of the annual 340-millirem natural background dose to individuals in Amargosa Valley. Section 8.2.7 discusses human health impacts to the public that could result from radiation exposures during construction, operation and monitoring, and closure for Inventory Module 1 or 2.

8.2.2.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

This section addresses potential nonradiological and radiological cumulative impacts to air quality from activities at the repository for the Proposed Action or Inventory Module 1 or 2 and other Federal,

Table 8-13. Estimated radiation doses to maximally exposed individuals and populations from radon-222 releases during closure phase.[a,b,c]

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual	Total	Maximum annual
	Proposed Action			
Dose to public				
MEI[d] (millirem)	3.0	0.39	4.3 - 9.4	0.57 - 0.87
80-kilometer population[e] (person-rem)	57	7.4	83 - 180	10 - 16
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved (surface) worker[f] (millirem)	0.014	0.0018	0.024 - 0.070	0.0030 - 0.0063
Yucca Mountain noninvolved (surface) worker population[g] (person-rem)	0.0040	0.00052	0.0070 - 0.015	0.00088 - 0.0014
Nevada Test Site noninvolved worker population[h] (person-rem)	0.0031	0.00041	0.0046 - 0.0099	0.00058 - 0.00089
	Inventory Module 1 or 2			
Dose to public				
MEI (millirem)	4.9	0.60	8.5 - 19	0.86 - 1.4
80-kilometer population (person-rem)	95	11	160 - 360	16 - 26
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved (surface) worker (millirem)	0.034	0.0040	0.063 - 0.14	0 - 0.010
Yucca Mountain noninvolved (surface) worker population (person-rem)	0.012	0.0013	0.015 - 0.026	0.0014 - 0.0019
Nevada Test Site noninvolved worker population (person-rem)	0.0052	0.00061	0.0090 - 0.020	0.00088 - 0.00015

a. Source: Appendix G, Section G-2.
b. Numbers are rounded to two significant figures.
c. The closure phase would last 10 to 7 years for the Proposed Action and 12 to 23 years for Inventory Module 1 or 2.
d. MEI = maximally exposed individual; at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker would be in the South Portal Development Area.
g. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

non-Federal, and private actions that would coincide with repository operations and potentially affect the air quality within the geographic boundaries of repository air quality impacts.

To identify and quantify potential cumulative impacts on air resources from other actions, the Department used a 50-mile (80-kilometer) radius around the proposed repository as the region of influence. However, because of the distances involved and the dispersion afforded by distance and different wind directions, the potential for overlap of plumes from multiple actions would be greatest for those actions that are in close proximity to each other (that is, a few miles). Beyond that, the degree of plume overlap is less certain and indeed may not exist.

8.2.2.2.1 *Nonradiological Air Quality*

Construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository would have very small impacts on regional air quality for the Proposed Action or for Inventory Module 1 or 2. Annual average concentrations of criteria pollutants at the land withdrawal boundary would be 1 percent or less of applicable regulatory limits except for PM_{10}, which the analysis estimated would be as much as 6.5 percent of the regulatory limit at the land withdrawal boundary. This estimate does not consider standard dust suppression activities (such as wetting), so actual concentrations probably would be much lower.

DOE has monitored particulate matter concentrations in the Yucca Mountain region since 1989; gaseous criteria pollutants were monitored from October 1991 through September 1995. Concentrations were well below applicable National Ambient Air Quality Standards (see Chapter 3, Section 3.1.2.1). In 1990, DOE also measured ambient air quality in several Nevada Test Site areas for short-term concentrations of sulfur dioxide, carbon monoxide, and PM_{10} (DIRS 101811-DOE 1996, Volume I, pp. 4-146 and 4-148).

The measurements were all lower than the applicable short-term (1-hour, 3-hour, 8-hour, and 24-hour) limits.

Pollutant concentrations related to Nevada Test Site activities would be well below ambient air quality standards and would not increase ambient pollutant concentrations above standards in Nye County (DIRS 101811-DOE 1996, Volume I, p. 4-146). Therefore, DOE expects the cumulative impacts from proposed repository and Nevada Test Site operations to be very small.

Other actions discussed in Section 8.1 would be unlikely to have cumulative impacts with the repository because they are sufficiently far away that plumes would have limited potential for overlap. Further, the responsible agencies would take measures for each action to minimize regional air impacts.

Repository activities would have no effect on air quality in the Las Vegas Valley air basin, which is a nonattainment area for carbon monoxide and PM_{10}, because the Las Vegas Valley air basin lies approximately 120 kilometers (75 miles) southeast of the proposed repository site.

8.2.2.2.2 *Radiological Air Quality*

Past activities at the Nevada Test Site are responsible for the seepage of radioactive gases from underground testing areas and slightly increased krypton-85 levels on Pahute Mesa in the northwest corner of the Nevada Test Site (see Figure 8-2). Some radioactivity on the site is attributable to the resuspension of soils contaminated from past aboveground nuclear weapons testing (DIRS 101811-DOE 1996, Volume I, p. 4-149). Current Nevada Test Site defense program activities have not resulted in detectable offsite levels of radioactivity. As discussed in Chapter 3, Section 3.1.8.2, estimated radiation doses to the public during 1999 were 0.12 millirem to the maximally exposed individual [a hypothetical resident of Springdale, Nevada, which is about 14 kilometers (19 miles) north of Beatty (see Figure 8-2)] and 0.38 person-rem to the population within 80 kilometers (50 miles) of Nevada Test Site airborne emission sources (DIRS 146592-Black and Townsend 1998, p. 7-1). The radiation dose estimates from repository construction, operation and monitoring, and closure (see Tables 8-10, 8-11, 8-12, and 8-13) would add to these estimates assuming the exposed individuals and population were the same (they are not). Conservatively adding the 1999 maximally exposed individual dose from the Nevada Test Site to the highest estimated average annual dose to the maximally exposed individual from repository operations (hypothetical individual located at the southern border of the land withdrawal area) (2.2 millirem) resulted in a cumulative dose of 2.3 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 15 percent of this standard. This dose would also represent 0.68 percent of the annual 340-millirem natural background radiation dose to individuals in Amargosa Valley. Conservatively adding the 1999 Nevada Test Site and highest estimated annual repository population dose (42 person-rem) results in a cumulative dose of 42 person-rem. No latent cancer fatalities to the population would be expected from this cumulative exposure (see Section 8.2.7).

Chapter 3 discusses potential radiological doses from past weapons testing at the Nevada Test Site. Residents who were present during the periods when such testing (in particular, atmospheric weapons testing from the 1950s to the early 1960s) occurred could have received as much as 5 rem to the thyroid gland from iodine-131 releases. Using a tissue weighting factor of 0.03 as specified in International Commission on Radiological Protection Publication 26 (DIRS 101075-ICRP 1977, all) this equates to an effective dose equivalent of about 150 millirem. Because of the length of time since atmospheric weapons testing ended, essentially all of this dose has already occurred. This dose would apply only to those residents who lived in the region of influence during the period of atmospheric weapons testing. DOE has not added this dose to the maximally exposed individual dose, but has included this information here so long-term residents in the region of influence can evaluate their potential for impacts from past nuclear weapons testing. (DOE has also included this information in the air quality portion of Table 8-60.)

The only other activity identified in the 80-kilometer (50-mile)-radius region of influence that could affect radiological air quality is a low-level radioactive disposal site near Beatty, Nevada, which was officially closed on January 1, 1993. The physical work of a State-approved Stabilization and Closure Plan ended in July 1994. Custodianship of the site has been transferred to the State of Nevada. Monitoring is continuing at the site to ensure that any radioactive material releases to the air continue to be low (DIRS 102171-NSHD 1999, Section on the Bureau of Health Protection Services).

8.2.3 HYDROLOGY

8.2.3.1 Surface Water

Potential impacts to surface waters from the Proposed Action would be relatively minor and limited to the immediate vicinity of land disturbances associated with the action (see Chapter 4, Section 4.1.3.2, and the floodplain/wetlands assessment in Appendix L). Surface-water impacts of primary concern would include the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage

This section addresses these impact areas in a discussion of possible increases or other changes that could occur as a result of the emplacement of Inventory Module 1 or 2. To be cumulative, other Federal, non-Federal, or private action effects would have to occur in the immediate area because of the transient nature of the surface water from the repository (that is, stormwater runoff). No currently identified actions have met this criterion.

Introduction and Movement of Contaminants

For Inventory Module 1 or 2, there would be essentially no change in the potential for soil contamination during the construction, operation and monitoring, and closure phases. There would be no change in the types of contaminants present nor would there be changes in operations that would make spills or releases more likely. Similarly, there would be no change in the threat of flooding to cause contaminant releases beyond that described for the Proposed Action.

Changes to Runoff or Infiltration Rates

Compared to the estimated area of land disturbed under the Proposed Action, Inventory Module 1 or 2 would require the disturbance of additional land for the corresponding repository operating mode (see Table 8-4). A maximum of about 5.5 square kilometers (1,400 acres) of land would be newly disturbed for Module 1 or 2 for the lower-temperature mode if surface aging was included. This increase in disturbed land would still be a relatively small portion of the natural drainage areas and would make little difference in the amount of water that soaked into the ground or reached the intermittently flowing drainage channels. Disturbed areas not covered by structures would slowly return to conditions more similar to those of the surrounding undisturbed ground.

Alterations of Natural Drainage

No additional actions or land disturbances associated with Inventory Module 1 or 2 would involve a potential to alter noteworthy natural drainage channels in the area. The excavated rock pile and its increased size for Module 1 or 2 would be in an area that would obstruct a very small portion of overland drainage. Potential impacts to floodplains would be the same as those described for the Proposed Action (see Chapter 4, Section 4.1.3.3). The construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on which routes DOE selected. Appendix L contains a floodplain/wetlands assessment that describes the actions DOE could take to construct, operate, and maintain a branch rail line or highway route in the Yucca Mountain vicinity.

8.2.3.2 Groundwater

8.2.3.2.1 *Inventory Module 1 or 2 Impacts*

Potential groundwater impacts would be related to the following:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer
- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones during the active life of the repository
- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

Changes to Infiltration and Aquifer Recharge. If DOE emplaced Inventory Module 1 or 2, changes related to infiltration and recharge rates would be limited to three areas: a possible increase in the size of the excavated rock pile, an increase in the number of ventilation shaft operations areas, and an extended scope for subsurface activities. The following paragraphs discuss these items.

Additional land disturbance anticipated during the operation and monitoring phase would be the continued growth of the excavated rock pile. Depending on the repository operating mode, this could involve as much as about 0.5 square kilometer (120 acres) of additional land over that required for the Proposed Action (see Table 8-4). Although the excavated rock pile could have different infiltration rates than undisturbed ground, it probably would not be a recharge location because of the extended depth of unconsolidated material, nor would it be likely to cause a large change in the amount of water that would otherwise reach recharge areas such as drainage channels.

Increased land disturbance would result from the additional ventilation shaft operation areas and the access roads that would be required as the repository footprint size increased to accommodate the Module 1 or 2 inventory. Depending on the repository operating mode, this could involve an additional 0.3 to 0.47 square kilometer (74 to 120 acres) of land disturbance over that required for these elements of the Proposed Action (see Table 8-4). These areas of disturbance would be primarily on steeper terrain, uphill from the portal areas, where unconsolidated material is likely thin and where disturbances could expose fractured bedrock. Infiltration rates could be increased notably in such areas as a result. However, much of the disturbed area would be capped with road material or equipment pads, and the amount of disturbed land would still be small in comparison to the surrounding undisturbed area.

Underground activities and their associated potential to contribute to the deep infiltration of water would be basically the same as those described for the Proposed Action, except emplacement drift construction would take an estimated 36 years to complete with either Inventory Module 1 or 2, compared to 22 years for the Proposed Action (see Table 8-3). As described for the Proposed Action, the quantities of water in the subsurface not removed to the surface by ventilation or pumping and thus available for infiltration

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would be small and primarily limited to the duration of drift development when the largest quantities of water would be used in the subsurface for dust control.

Potential for Contaminant Migration to Groundwater Zones. Neither Inventory Module 1 nor 2 would involve additional actions likely to increase the potential for contaminant releases to the environment. The only possible exception to this could be the extended period of subsurface excavation activities to accommodate the additional inventory. However, this exception would be an extension of activities with minimal potential to involve substantial contaminant releases.

Potential to Deplete Groundwater Resources. Anticipated annual water demand for Inventory Module 1 or 2 would be the same or very similar to that projected for the Proposed Action. Table 8-14 summarizes estimated annual water demands for both the Proposed Action and Inventory Module 1 or 2. The table indicates no notable change in water demand during construction.

Table 8-14. Estimated annual water demand (acre-feet)[a] for the Proposed Action and Inventory Module 1 or 2.

	Water demand (acre-feet/year)[a]		
		Operating mode	
Phase	Duration (years)	Higher-temperature	Lower-temperature
	Proposed Action		
Construction	5	160	190 to 210
Operation and monitoring (by activity)			
Emplacement and development activities			
Combined emplacement and development	22	230	250 to 290
Subsequent emplacement or aging only[b]	2 or 28	180	90 to 190
Monitoring activities			
Initial decontamination	3	220	200 to 230
Subsequent monitoring/caretaking	73 to 297	6	3 to 6
Closure	10 to 17	81	70 to 84
	Inventory Module 1 or 2		
Construction	5	160	190 to 210
Operation and monitoring (by activity)			
Emplacement and development activities			
Combined emplacement and development	36	250	240 to 320
Subsequent emplacement only[b]	2 or 15	180	90 to 190
Monitoring activities			
Initial decontamination	3	220	200 to 230
Subsequent monitoring/caretaking	59 to 297	6	4 to 6
Closure	12 to 23	83	73 to 91

a. To convert acre-feet to cubic meters, multiply by 1,233.49.

b. Unless surface aging is involved, the period during which development was complete and only emplacement being conducted would last 2 years. This higher duration listed is applicable only to the lower-temperature repository operating mode that includes surface aging.

Projected annual water demand during emplacement and development activities of the operation and monitoring phase (as listed in Table 8-14) would be very similar, but generally a little higher under Inventory Module 1 or 2. However, the difference in total water demand would be greater when the change in the duration of the annual demand is taken into consideration. That is, this phase of repository activities, which would have the highest annual water demand, is extended from 22 to 36 years with the Module 1 or 2 inventory. On an annual basis, water demand would increase no more than 4 to 10 percent over that for the Proposed Action but, during the entire 36-year period, Inventory Module 1 or 2 would result in an increased water demand by as much as about 80 percent, depending on the repository operating mode.

Projected annual water demand during monitoring activities of the operation and monitoring phase would be basically the same under either the Proposed Action or Inventory Module 1 or 2. In either case, the relatively high demands listed in Table 8-14 would last only about 3 years during surface facility decontamination, after which the annual demand would drop drastically for the remainder of this long-duration activity. The closure phase for Module 1 or 2 shows there would be only a slight increase in projected annual water demand in comparison to the Proposed Action. The fact that the duration of the closure phase would be longer under Module 1 or 2 would increase the difference on a total-phase basis, but the increases would still be minor.

Potential impacts to water resources under Inventory Module 1 or 2 would be very similar to those under the Proposed Action because the annual water demand would change little, and the best understanding of the groundwater resource is that it is replenished on an annual basis as gauged by the perennial yield of the groundwater basin. Under Module 1 or 2, the repository's annual water demand from the western two-thirds of the Jackass Flats basin would remain below the lowest estimated value for its perennial yield of [720,000 cubic meters (580 acre-feet)] (see Chapter 3, Table 3-11). See Chapter 4, Section 4.1.3.3 for more information on regional groundwater usage and demand.

8.2.3.2.2 *Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions*

Potential impacts to groundwater, as described in Chapter 4, Section 4.1.3.3, and in Section 8.2.3.2.1, for the Proposed Action and Inventory Module 1 or 2 would be small and limited to the immediate vicinity of land disturbances associated with the action. The exceptions to this would be the potential impact from water demands on groundwater resources and potential impacts from contaminants in groundwater. With these exceptions, other Federal, non-Federal, or private action effects would have to occur in the same region of influence to be cumulative with those resulting from the Proposed Action or Inventory Module 1 or 2, and no currently identified actions meet this criterion.

The remainder of this discussion addresses potential impacts to groundwater resources from water demand. Section 8.3 addresses long-term impacts of contaminants in groundwater.

The discussion of impacts to groundwater resources in Chapter 4, Section 4.1.3.3, includes ongoing water demands from Area 25 of the Nevada Test Site. Area 25 is the proposed location of the primary repository surface facilities. It is also the location of wells J-12 and J-13, which would provide water for the Proposed Action and for ongoing Nevada Test Site activities in this area. The estimated water demand for these ongoing activities is 340,000 cubic meters (280 acre-feet) a year (DIRS 103226-DOE 1998, Table 11-2, p. 11-6).

Water demand during emplacement and development activities of the operation and monitoring phase under Inventory Module 1 or 2 combined with the baseline demands from Nevada Test Site activities would exceed the lowest perennial yield estimate under the lower-temperature repository operating modes if certain features were enacted. The highest annual water demand attributed to the lower-temperature operating mode with maximum package spacing, in combination with ongoing Nevada Test Site water demands, would exceed the lowest estimate of perennial yield, but only marginally. The worst-case scenario for repository water demand (maximum spacing and surface aging under the lower-temperature operating mode) added to the Nevada Test Site demand would total about 240,000 cubic meters (600 acre-feet) per year compared to 720,000 cubic meters (580 acre-feet), the lowest estimate of perennial yield for the western two-thirds of Jackass Flats. Besides these exceptions, the combined water demands would be below the lowest estimate of perennial yield. None of the water demand estimates would approach the high estimate of perennial yield for the entire Jackass Flats hydrographic basin, which is 4.9 million cubic meters (4,000 acre-feet) (see Chapter 3, Table 3-11). Potential impacts to groundwater resources from this combined demand would be no different than those described in Chapter 4,

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Section 4.1.3.3. That is, some decline in the water level would be likely near the production wells, and water elevation decreases at the town of Amargosa Valley would probably be no more than 0.4 to 1.1 meter (1.2 to 3.6 feet) (see Section 4.1.3.3). The reduction in underflow from the Jackass Flats hydrographic area to the Amargosa Desert hydrographic area would be less than the quantity of water actually withdrawn from the upgradient area because there would probably be minor changes in groundwater flow patterns as the water level adjusted to the withdrawals. Groundwater flow models predict the reduction in underflow to the Amargosa Desert would be no higher than 160,000 to 180,000 cubic meters (130 to 150 acre-feet) per year (see Section 4.1.3.3).

The Nevada Test Site EIS (DIRS 101811-DOE 1996, pp. 3-18, 3-19, and 3-34) indicates that the potential construction and operation of a Solar Enterprise Zone facility would represent the only action that would cause water withdrawals on the Test Site to exceed past levels. That EIS estimates that this demand would be greater than the highest estimates of the basin's perennial yield. Therefore, cumulative impacts from the Solar Enterprise Zone facility are likely. DOE is considering several locations for the Solar Enterprise Zone facility, one of which is Area 25. If DOE built this facility in Area 25, it would obtain water from the Jackass Flats hydrologic area, and possibly from other hydrologic areas.

Cumulative demands on the Jackass Flats hydrographic area could have long-term impacts on water availability in the downgradient aquifers beneath the Amargosa Desert. The groundwaters in these areas are hydraulically linked, but the exact nature and extent of that link is still a matter of study and some speculation. However, the amount of water already being withdrawn in the Amargosa Desert [averaging about 17 million cubic meters (14,000 acre-feet) of water per year from 1995 through 1997 (see Chapter 3, Table 3-11)] is much greater than the quantities being considered for withdrawal from Jackass Flats. If water pumpage from Jackass Flats affected water levels in the Amargosa Desert, the impacts would be small in comparison to those caused by local pumping in that area.

A report from the Nye County Nuclear Waste Repository Office (DIRS 103099-Buqo 1999, pp. 39 to 53) provides a perspective of potential cumulative impacts with that County as the center of interest. The Nye County report evaluates impacts to all water resources potentially available in the entire county, whereas this EIS focuses principally on impacts to the Jackass Flats groundwater basin (the source of water that DOE would use for the repository) and the groundwater system that could become contaminated thousands of years in the future. Nye County reports that the potential cumulative impacts would include additive contamination as radionuclides ultimately reached the groundwater, constraints on development of groundwater due to land withdrawal, and reduction of water available for Nye County development because of use by Federal agencies (DIRS 103099-Buqo 1999, pp. 49 to 51).

8.2.4 BIOLOGICAL RESOURCES

Impacts to biological resources from Inventory Module 1 or 2 would be similar to impacts that would occur as a result of the Proposed Action evaluated in Chapter 4, Section 4.1.4. Those impacts would occur primarily as a result of site clearing, placement of material in the excavated rock pile, habitat loss, and the loss of individuals of some animal species during site clearing and from vehicle traffic.

Inventory Module 1 or 2 would require disturbing biological resources in a larger area under each thermal load scenario than would be disturbed under the Proposed Action, primarily because the excavated rock pile would be larger (Table 8-15).

Repository construction and the excavated rock pile to support Inventory Module 1 or 2 would disturb up to 5.5 square kilometers of previously undisturbed land. Disturbances would occur in areas dominated by Mojave mixed scrub and salt desert scrub land cover types. These cover types are widespread in the withdrawal area and in Nevada. This disturbed area is larger than that for the Proposed Action and would

Table 8-15. Area of land cover types in analyzed withdrawal area disturbed by construction and the excavated rock pile (square kilometers).[a,b,c]

Land cover type	Area in Nevada	Area in analyzed withdrawal area[d]	Operating mode: Higher-temperature	Operating mode: Lower- temperature
			Proposed Action	
Blackbrush	9,900	140	0.0	0 - 0.2
Creosote-bursage	15,000	300	0.6	0.6 - 0.7
Mojave mixed scrub	5,700	120	2.2	2.4 - 3.6
Sagebrush	67,000	16	0.0	0
Salt desert scrub	58,000	20	0.0	0
Previously disturbed[e]	NA[f]	4	1.5	1.5
Totals	***NA***	***600***	***4.3***	***4.5 - 6***
			Inventory Module 1 or 2	
Blackbrush	9,900	140	0.0	0 - 0.2
Creosote-bursage	15,000	300	0.6	0.6 - 0.7
Mojave mixed scrub	5,700	120	3.0	3.2 - 4.6
Sagebrush	67,000	16	0.0	0
Salt desert scrub	58,000	20	0.0	0
Previously disturbed[e]	NA	4	1.5	1.5
Totals	***NA***	***600***	***5.1***	***5.4 - 7***

a. Source: Facility diagrams from DIRS 104523-CRWMS M&O (1999, Figures 6.1.7-1, 6.1.7-2, 6.2.7-1, and 6.2.7-2; pp. 6-42, 6-43, 6-84, and 6-85) overlain on the land cover types map; DIRS 104589-CRWMS M&O (1998, p. 9 as adapted) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. Totals might differ from sums of values due to rounding.
d. A small area [0.016 square kilometer (4 acres)] of the pinyon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
e. Estimate of land previously disturbed in support of the proposed repository.
f. NA = not applicable.

affect vegetation on approximately 1 percent of the previously undisturbed land within the land withdrawal area.

Releases of radioactive materials would not adversely affect biological resources. Routine releases would consist of noble gases, primarily krypton-85 and radon-222. These gases would not accumulate in the environment around Yucca Mountain and would result in low doses to plants or animals.

Overall impacts to biological resources from Inventory Module 1 or 2 would be very small. Species at the repository site are generally widespread throughout the Mojave or Great Basin Deserts and repository activities would affect a very small percentage of the available habitat in the region. Changes in the regional population of any species would be undetectable and no species would be threatened with extinction. The removal of vegetation from the small area required for Module 1 or 2 or the local loss of small numbers of individuals of some species due to site clearing and vehicle traffic would not affect regional biodiversity and ecosystem function. The loss of desert tortoise habitat and small numbers of tortoises under Module 1 or 2 would have no impact on recovery efforts for this threatened species.

Activities associated with other Federal, non-Federal, and private actions in the region should not add measurable impacts to the overall impact on biological resources. However, as stated in the Nevada Test Site EIS (DIRS 101811-DOE 1996, p. 6-16), cumulative impacts to the desert tortoises would occur throughout the region, although the intensity of the impacts would vary from location to location. The largest impact to the habitat probably would occur in the Las Vegas Valley region. The Clark County Desert Conservation Plan authorizes the taking of all tortoises on 445 square kilometers (110,000 acres) of non-Federal land in the County, and on 12 square kilometers (3,000 acres) disturbed by Nevada

Department of Transportation activities in Clark and adjacent counties. The plan also authorizes several recovery units designed to optimize the survival and recovery of this threatened species. Potential land disturbance activities at the Nevada Test Site under the expanded use alternative represent a small amount of available desert tortoise habitat and will not add measurably to the loss of this species (DIRS 101811-DOE 1996, p. 6-16). As discussed in Chapter 4, Section 4.1.4, repository construction activities would involve the loss of an amount of desert tortoise habitat that would be small in comparison to its range. Yucca Mountain is at the northern end of the range of this species. DOE anticipates that small numbers of tortoises would be killed inadvertently by vehicle traffic during the repository construction, operation and monitoring, and closure phases.

8.2.5 CULTURAL RESOURCES

The only identified actions that could result in cumulative cultural resource impact in the Yucca Mountain site vicinity are Inventory Module 1 or 2. The emplacement of either module would require small additional disturbances to land in areas already surveyed during site characterization activities (see Table 8-4). Because repository construction, operation and monitoring, and closure would be Federal actions, DOE would identify and evaluate cultural resources, as required by Section 106 of the National Historic Preservation Act, and would take appropriate measures to avoid or mitigate adverse impacts to such resources. As a consequence, archaeological information gathered from artifact retrieval during land disturbance would contribute additional cultural resources information to the regional data base for understanding past human occupation and use of the land. However, there would be a potential for illicit or incidental vandalism of archaeological or historic sites and artifacts as a result of increased activities in the repository area, which would be extended for Module 1 or 2 (see Table 8-3), and this could contribute to an overall loss of regional cultural resources information.

The Native American view of resource management and preservation is holistic in its definition of cultural resources, incorporating all elements of the natural and physical environment in an interrelated context (DIRS 102043-AIWS 1998, all). The Native American perspective on cultural resources is further discussed in Chapter 3, Section 3.1.6. Potential impacts resulting from the Proposed Action described in Chapter 4, Section 4.1.5, would also apply to Inventory Module 1 or 2.

8.2.6 SOCIOECONOMICS

8.2.6.1 Inventory Modules 1 and 2 Impacts

This section addresses potential socioeconomic impacts associated with Inventory Module 1 or 2 and concludes that impacts for Inventory Module 1 or 2 would be essential the same during construction phase as the Proposed Action, slightly greater during the development and emplacement phases than the Proposed Action, the same during the monitoring phase, and slightly greater than impacts for the Proposed Action during the closure phase. The impacts in all phases for Module 1 or 2 would be small, as are impacts estimated for the Proposed Action (see Chapter 4, Section 4.1.6). DOE analyzed both the higher-temperature operating mode and the lower-temperature operating mode. Table 8-16 summarizes the peak direct employment levels during all phases for the Proposed Action and for the Inventory Modules.

Construction

DOE expects the construction phase to last for 5 years. The construction phase for Inventory Module 1 or 2 would require approximately 1,800 workers in the peak year, the same as the Proposed Action (see Table 8-16). The impacts for Module 1 or 2 would therefore be the same as those for the Proposed Action.

Table 8-16. Estimated peak direct employment level impacts from repository phases.[a,b]

Phase	Proposed Action: Higher-temperature	Proposed Action: Lower-temperature	Inventory Module 1 or 2: Higher-temperature	Inventory Module 1 or 2: Lower-temperature
Construction	1,800	1,800	1,800	1,800
Operation and Monitoring				
Development, emplacement	1,700	1,800 - 1,900	1,700	1,700 - 2,600
Monitoring[c]	120	40 - 120	140	130 - 140
Closure	960	960	970	1,100 - 1,200

a. Includes approximately 220 currently employed workers.
b. Numbers rounded to two significant places.
c. Excludes approximately 1,100 workers required for decontamination (monitoring period). Number of required workers is approximately the same for both operating modes for Inventory Module 1 or 2.

Operation and Monitoring

For the Proposed Action, DOE expects the repository development to last for 22 years and emplacement to last for 24 years. With Modules 1 or 2, development would last 36 years and emplacement 38 years. If a design with an aging facility were selected, emplacement activities would last 50 years for the Proposed Action or 51 years for Module 1 or 2. Monitoring activities occur concurrently and then extend beyond the emplacement period for up to 300 years. Employment levels for Module 1 or 2 during this phase could require approximately 700 more workers than the estimated worker requirement for the Proposed Action (see Table 8-16). Although the overall duration of the operation phase, including the development, emplacement, and monitoring activities, varies in length depending on the final scenario of the flexible design, the primary difference between Inventory Module 1 or 2 and the Proposed Action is the increased duration of development and emplacement activities (by 14 years).

The annualized impacts during development and emplacement activities for Inventory Module 1 or 2 would be similar to those for the Proposed Action, but these impacts would continue for an additional 14 years. As with the Proposed Action, direct and indirect increases in regional employment, population, Gross Regional Product, real disposal income, and government expenditures would be small, 3 percent or less of the baselines, for affected counties. No substantial socioeconomic impacts would be likely during the operations phase.

Closure

DOE expects the closure phase to last between 12 and 23 years. Although the required staffing level for Inventory Module 1 or 2 would be slightly greater, but similar in impact, to that of the Proposed Action, Inventory Module 1 or 2 would require more time. Closure would last up to 23 years for Inventory Module 1 or 2. However, as with the Proposed Action, because work force demands would be less than the peak year employment demands during the operations or construction phase, impacts to regional employment, population, Gross Regional Product, real disposal income, and government expenditures would be very small. No substantial impact would likely occur during the closure for Inventory Module 1 or 2.

8.2.6.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

Reasonably foreseeable future actions at the Nevada Test Site could affect the socioeconomic region of influence (Nye, Clark, and Lincoln Counties). Sections 8.1.1 and 8.1.2 discuss other activities in the region that could have a socioeconomic impact. However, most of these activities have either already occurred or would occur prior to peak employment associated with the proposed repository. Because of the minimal amount of overlap that would occur in the activities, the affected communities would have more time to assimilate any new residents that might relocate to the region. Thus, no substantial impacts would be likely to occur from these activities.

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8.2.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

This section discusses the short-term health and safety impacts to workers and to members of the public (radiological only) associated with construction, operation and monitoring, and closure activities at the Yucca Mountain site for Inventory Module 1 or 2 (Sections 8.2.7.1 through 8.2.7.3). Section 8.2.7.4 provides a summary of these impacts. Appendix F contains the approach and methods used to estimate the health and safety impacts and additional detailed results for Module 1 or 2 health and safety impacts to workers.

With one exception, no other Federal, non-Federal, or private actions were identified with spatially or temporally coincident short-term impacts in the region of influence that would result in cumulative health and safety impacts with those of the proposed Yucca Mountain Repository. Chapter 3 discusses the potential radiological doses from past weapons testing at the Nevada Test Site. While all of the current population was not present at the time of the testing, residents who were present during the time periods when weapons testing (in particular, atmospheric weapons testing from the 1950s to the early 1960s) occurred could have received as much as 5 rem to the thyroid gland from iodine-131 releases. Using a tissue-weighting factor of 0.03 as specified in International Commission on Radiological Protection Publication 26 (DIRS 101075-ICRP 1977, all), this would equate to an effective dose equivalent of about 150 millirem. Because of the length of time since atmospheric weapons testing ceased, essentially all of this dose has already occurred. This dose would apply only to those residents who lived in the region of influence during the time period of atmospheric weapons testing. DOE has not added this dose to the maximally exposed individual dose, but DOE has included this information so that long-term residents in the region of influence can evaluate their potential for impacts from past nuclear weapons testing. (The dose is included in the risk estimates in Table 8-60 for the summary of public health and safety.)

With the increased number of persons living and working in the region, the number of injuries and fatalities from nonrepository-related activities would increase. However, injury and mortality incidence should remain unchanged or decrease, assuming the continued enforcement of occupational and public health and safety regulations.

Regarding the health and safety impact analysis for Inventory Module 1 or 2, the radiological characteristics of the spent nuclear fuel and high-level radioactive waste would be the same as those for the Proposed Action; there just would be more material to emplace. As described in Appendix A, the radioactive inventory (and radiological properties) of the Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste is much less than that for spent nuclear fuel and high-level radioactive waste. Therefore, the subsurface emplacement of the material in Inventory Module 2 would not greatly increase radiological impacts to workers over those estimated for Module 1. For the surface facility evaluation, the number of workers would be the same for Inventory Module 1 or 2 (DIRS 104508-CRWMS M&O 1999, Section 3.3, third paragraph). Therefore, DOE did not perform separate impact analyses for Modules 1 and 2.

The primary changes in the parameters that would affect the magnitude of the worker health and safety impacts between the Proposed Action and Inventory Module 1 or 2 would be the periods required to perform the work and the numbers of workers for the different phases. Appendix F, Table F-43 p. 2 contains a detailed breakdown of the estimates for the involved and noninvolved workforce for the repository phases for Inventory Module 1 or 2 in terms of full-time equivalent worker-years.

For the public, the principal changes in parameters that would affect the magnitude of the health impact estimates would be the length of the various phases and the rate at which air would be exhausted from the repository. The exhaust rate of the subsurface ventilation system would affect both the radon-222 concentrations to which subsurface workers would be exposed and the quantity of radon-222 released to

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the environment. Appendix G, Section G.2.3.1, discusses radon-222 concentrations in the subsurface environment and release rates to the environment from the various project phases.

8.2.7.1 Construction

This section presents estimates of health and safety impacts to repository workers and members of the public for the construction phase. The values are similar to those for the Proposed Action because the length of the construction phase would be the same and activities would be similar.

Industrial Hazards

Table 8-17 lists health and safety hazards to workers common to the workplace. They are based on the health and safety loss statistics listed in Appendix F, Tables F-4 and F-5. For Inventory Module 1 or 2 these impacts would be independent of the operating mode because the number of workers would be the same for both operating modes.

Table 8-17. Summary of industrial hazard health and safety impacts to facility workers during the construction phase.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	340	340 - 370
Lost workday cases	160	160 - 180
Fatalities	0.16	0.16 - 0.18
Noninvolved worker		
Total recordable cases of injury and illness	55	55 - 61
Lost workday cases	27	27 - 30
Fatalities	0.048	0.048 - 0.054
All workers		
Total recordable cases of injury and illness	400	400 - 430
Lost workday cases	190	190 - 210
Fatalities	0.21	0.21 - 0.23
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	340	340 - 370
Lost workday cases	160	160 - 180
Fatalities	0.16	0.16 - 0.18
Noninvolved worker		
Total recordable cases of injury and illness	55	55 - 61
Lost workday cases	27	27 - 30
Fatalities	0.048	0.048 - 0.054
All workers		
Total recordable cases of injury and illness	400	400 - 430
Lost workday cases	190	190 - 210
Fatalities	0.21	0.21 - 0.23

a. Source: Appendix F, Table F-12.

Radiological Health Impacts

This analysis presents radiological health impacts in terms of doses and resultant latent cancer fatalities. Estimated doses were converted to estimates of latent cancer fatality using a dose-to-risk conversion factor of 0.0004 and 0.0005 latent cancer fatality per person-rem for workers and the public, respectively (see Appendix F, Section F.1.1.5).

Workers. Spent nuclear fuel and high-level radioactive waste would not be present during the construction phase. Potential radiological impacts to surface workers during this phase would be limited to those from releases of naturally occurring radon-222 and its decay products with the subsurface ventilation exhaust (these impacts are presented in Section 8.2, Table 8-10). Subsurface workers would incur exposure from radiation resulting from radionuclides in the walls of the drifts and from inhalation of radon-222 in the subsurface atmosphere. Surface worker exposure would be very small compared to those for subsurface workers. The radiological doses and health impacts for Inventory Module 1 or 2 are listed in Table 8-18. The Module 1 or 2 impacts would be independent of the operating mode because the subsurface workforce would not change.

Table 8-18. Summary of radiological health impacts to workers from all activities during construction phase.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Dose to maximally exposed worker (millirem)	1,300	1,300
Probability of latent cancer fatality	0.00052	0.00052
Collective dose (person-rem)	680	680
Number of latent cancer fatalities	0.27	0.27
Noninvolved worker		
Dose to maximally exposed worker (millirem)	330	330
Probability of latent cancer fatality	0.00013	0.00013
Collective dose (person-rem)	37	37
Number of latent cancer fatalities	0.015	0.015
All workers		
Collective dose (person-rem)	720	720
Number of latent cancer fatalities	0.29	0.29
	Inventory Module 1 or 2	
Involved worker		
Dose to maximally exposed worker (millirem)	1,300	1,300
Probability of latent cancer fatality	0.00052	0.00052
Collective dose (person-rem)	680	680
Number of latent cancer fatalities	0.27	0.27
Noninvolved worker		
Dose to maximally exposed worker (millirem)	330	330
Probability of latent cancer fatality	0.00013	0.00013
Collective dose (person-rem)	37	37
Number of latent cancer fatalities	0.015	0.015
All workers		
Collective dose (person-rem)	720	720
Number of latent cancer fatalities	0.29	0.29

a. Source: Appendix F, Table F-11.

Public. Potential radiological impacts to the public during the construction phase would be limited to those from the release of naturally occurring radon-222 with the exhaust from subsurface ventilation. Table 8-19 presents radiological health impacts for the public surrounding the proposed repository.

8.2.7.2 Operations

This section presents estimates of health and safety impacts to workers and members of the public during the operations period. The primary differences between Inventory Module 1 or 2 and the Proposed Action would be the longer durations for development and emplacement activities. Under Module 1 or 2,

Table 8-19. Radiological health impacts to the public from the construction phase.[a]

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual	Total	Annual
	Proposed Action			
Dose to public				
Offsite MEI[b] (millirem)	1.7	0.43	1.7 - 2	0.43 - 0.53
80-kilometer population (person-rem)	33	8.4	33 - 40	8.4 - 10
Offsite MEI probability of latent cancer fatality	8.5×10^{-7}	2.1×10^{-7}	8.5×10^{-7} - 0.000001	2.1×10^{-7} - 2.6×10^{-7}
80-kilometer population number of latent cancer fatalities	0.017	0.0042	0.017 - 0.02	0.0042 - 0.0052
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	1.7	0.43	2	0.52 - 0.53
80-kilometer population (person-rem)	33	8.4	39 - 40	10
Offsite MEI probability of latent cancer fatality	8.5×10^{-7}	2.1×10^{-7}	9.9×10^{-7} - 0.000001	2.6×10^{-7} - 2.6×10^{-7}
80-kilometer population number of latent cancer fatalities	0.017	0.0042	0.019 - 0.02	0.0051 - 0.0052

a. Sources: Chapter 4, Table 4-23; Appendix G, Section G.2.
b. MEI = maximally exposed individual.

it would take DOE 14 more years to complete drift development (36 years total) than for the Proposed Action and 14 more years to complete emplacement (38 years total) than for the Proposed Action.

Industrial Hazards

Table 8-20 lists health and safety impacts to workers from industrial hazards common to the workplace. These impacts would be about 50 to 60 percent greater than those calculated for the Proposed Action.

Radiological Impacts

Workers. Table 8-21 lists radiological doses and health impacts to workers during the operations period for Inventory Module 1 or 2. Appendix F contains additional detail and presents the radiological impacts for surface workers, subsurface workers, and monitoring activities. Radiological impacts to workers for Module 1 or 2 would be about 50 to 60 percent greater than those for the Proposed Action.

Public. Potential radiological impacts to the public from the operations period would result from the release of naturally occurring radon-222 and its decay products with the subsurface exhaust ventilation air and from radioactive gases, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations.

Table 8-22 lists the total radiological doses and radiological health impacts to the public from releases to the atmosphere of krypton-85 and radon-222 during the operations period. Radon-222 and its decay products would be the dominant dose contributors (greater than 99 percent).

8.2.7.3 Monitoring

This section contains estimates of the health and safety impacts to workers and members of the public for the monitoring period. The length of this period would depend on the operating mode; however, the monitoring phase for Inventory Module 1 or 2 would generally be shorter than the corresponding monitoring phase for the Proposed Action as shown in Table 8-3.

Industrial Hazards

Table 8-23 lists health and safety impacts to workers from hazards common to the workplace. As discussed above, the duration of the monitoring period for the Inventory Modules is shorter than that for the Proposed Action; therefore, the industrial safety impacts would be less for the Inventory Modules than for the Proposed Action.

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Table 8-20. Summary of industrial hazard health and safety impacts to facility workers during operations period.

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	1,200	1,200 - 1,700
Lost workday cases	590	620 - 840
Fatalities	0.9	0.91 - 1.4
Noninvolved worker		
Total recordable cases of injury and illness	300	310 - 470
Lost workday cases	150	150 - 230
Fatalities	0.31	0.31 - 0.45
All workers		
Total recordable cases of injury and illness	1,500	1,500 - 2,200
Lost workday cases	740	770 - 1,100
Fatalities	1.2	1.2 - 1.9
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	1,900	1,900 - 2,200
Lost workday cases	970	970 - 1,100
Fatalities	1.4	1.4 - 1.7
Noninvolved worker		
Total recordable cases of injury and illness	470	470 - 560
Lost workday cases	230	230 - 270
Fatalities	0.46	0.46 - 0.54
All workers		
Total recordable cases of injury and illness	2,400	2,400 - 2,800
Lost workday cases	1,200	1,200 - 1,400
Fatalities	1.9	1.9 - 2.2

a. Source: Appendix F, Tables F-22 and F-52.

Radiological Impacts

Workers. Table 8-24 lists radiological doses and health impacts from activities during the monitoring period. During this period the primary source of collective dose to the involved subsurface worker population would be the inhalation dose from radon-222 while the primary source of collective dose to the involved surface worker population would be direct exposure to the waste packages.

Public. Table 8-25 lists the radiological doses and health impacts to the public from activities during the monitoring period. The primary source of these impacts is the release of radon-222 via subsurface ventilation flow.

8.2.7.4 Closure

This section contains estimates of health and safety impacts to workers and members of the public for the closure phase.

Industrial Hazards

Table 8-26 lists health and safety impacts to workers from hazards common to the workplace. The impacts for Inventory Module 1 or 2 would be slightly greater than those for the Proposed Action.

Radiological Impacts

Workers. Table 8-27 lists radiological doses and health impacts to workers during the closure phase. Subsurface workers would be exposed to radon-222 from inhalation of air in the drifts, to external

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Table 8-21. Summary of radiological health impacts to workers from all activities during operations period.[a]

Worker group	Operating mode: Higher-temperature	Operating mode: Lower-temperature
	Proposed Action	
Involved worker		
Dose to maximally exposed worker (millirem)	15,000	15,000 - 30,000
Probability of latent cancer fatality	0.006	0.006 - 0.012
Collective dose (person-rem)	7,500	7,600 - 12,000
Number of latent cancer fatalities	3.0	3.0 - 4.8
Noninvolved worker		
Dose to maximally exposed worker (millirem)	1,500	1,500 - 1,800
Probability of latent cancer fatality	0.0006	0.0006 - 0.00072
Collective dose (person-rem)	150	160 - 170
Number of latent cancer fatalities	0.06	0.064 - 0.068
All workers		
Collective dose (person-rem)	7,700	7,800 - 12,000
Number of latent cancer fatalities	3.1	3.1 - 4.8
	Inventory Module 1 or 2	
Involved worker		
Dose to maximally exposed worker (millirem)	24,000	24,000 - 33,000
Probability of latent cancer fatality	0.0096	0.0096 - 0.013
Collective dose (person-rem)	12,000	12,000 - 15,000
Number of latent cancer fatalities	4.8	4.8 - 6
Noninvolved worker		
Dose to maximally exposed worker (millirem)	2,400	2,400
Probability of latent cancer fatality	0.00096	0.00096
Collective dose (person-rem)	180	180 - 190
Number of latent cancer fatalities	0.072	0.072 - 0.076
All workers		
Collective dose (person-rem)	12,000	12,000 - 15,000
Number of latent cancer fatalities	4.8	4.8 - 6

a. Source: Appendix F, Tables F-23 and F-53.

Table 8-22. Radiological health impacts to the public from the operations period.

Impact	Higher-temperature: Total	Higher-temperature: Maximum annual	Lower-temperature: Total	Lower-temperature: Annual
	Proposed Action			
Dose to public				
Offsite MEI[a] (millirem)	12	0.73	17 - 43	1 - 1.3
80-kilometer population (person-rem)	230	14	320 - 830	20 - 26
Offsite MEI probability of latent cancer fatality	0.000006	3.7×10^{-7}	8.3×10^{-6} - 0.000022	5.2×10^{-7} - 6.7×10^{-7}
80-kilometer population number of latent cancer fatalities	0.12	0.0071	0.16 - 0.42	0.01 - 0.013
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	22	0.94	31 - 66	1.3 - 2.2
80-kilometer population (person-rem)	430	18	600 - 1,300	26 - 42
Offsite MEI probability of latent cancer fatality	0.000011	4.7×10^{-7}	0.000016 - 0.000033	6.7×10^{-7} - 1.1×10^{-6}
80-kilometer population number of latent cancer fatalities	0.22	0.0091	0.3 - 0.64	0.013 - 0.021

a. MEI = maximally exposed individual.

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Table 8-23. Summary of industrial hazard health and safety impacts to facility workers during monitoring period.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	320	400 - 1,000
Lost workday cases	130	160 - 410
Fatalities	0.31	0.38 - 1
Noninvolved worker		
Total recordable cases of injury and illness	55	65 - 150
Lost workday cases	27	32 - 73
Fatalities	0.049	0.057 - 0.13
All workers		
Total recordable cases of injury and illness	380	470 - 1,200
Lost workday cases	160	190 - 480
Fatalities	0.36	0.44 - 1.1
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	290	450 - 1,100
Lost workday cases	120	180 - 440
Fatalities	0.28	0.43 - 1.1
Noninvolved worker		
Total recordable cases of injury and illness	51	74 - 160
Lost workday cases	25	36 - 78
Fatalities	0.045	0.065 - 0.14
All workers		
Total recordable cases of injury and illness	340	520 - 1,300
Lost workday cases	150	220 - 520
Fatalities	0.33	0.50 - 1.2

a. Source: Appendix F, Tables F-31 and F-59.

radiation from radionuclides in the rock in the drift walls, and to external radiation emanating from the waste packages.

Public. Potential radiation-related health impacts to the public from closure activities would result from releases of radon-222 in the subsurface ventilation flow. Section 8.2.2.1.2 describes radiation doses to the public for this phase. Table 8-28 lists radiological dose and health impacts for the closure phase. Radiological health impacts to the public for the inventory modules would be greater than those for the Proposed Action largely because of the longer time period for closure activities (see Table 8-3).

8.2.7.5 Summary

This section contains three summary tables:

- A summary of health impacts to workers from industrial hazards common to the workplace for all phases (Table 8-29)
- A summary of radiological doses and health impacts to workers for all phases (Table 8-30)
- A summary of radiological doses and health impacts to the public for all phases (Table 8-31)

Table 8-24. Summary of radiological health impacts to workers from all activities during monitoring period.[a]

Worker group	Operating mode: Higher-temperature	Operating mode: Lower-temperature
	Proposed Action	
Involved workers		
Dose to maximally exposed worker (millirem)	18,000	18,000
Probability of latent cancer fatality	0.0072	0.0072
Collective dose (person-rem)	1,100	1,500 - 4,300
Number of latent cancer fatalities	0.44	0.6 - 1.7
Noninvolved workers		
Dose to maximally exposed worker (millirem)	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072
Collective dose (person-rem)	36	46 - 140
Number of latent cancer fatalities	0.014	0.018 - 0.056
All workers		
Collective dose (person-rem)	1,100	1,500 - 4,400
Number of latent cancer fatalities	0.44	0.6 - 1.8
	Inventory Module 1 or 2	
Involved workers		
Dose to maximally exposed worker (millirem)	18,000	18,000
Probability of latent cancer fatality	0.0072	0.0072
Collective dose (person-rem)	990	1,700 - 4,500
Number of latent cancer fatalities	0.4	0.68 - 1.8
Noninvolved workers		
Dose to maximally exposed worker (millirem)	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072
Collective dose (person-rem)	31	56 - 150
Number of latent cancer fatalities	0.012	0.022 - 0.06
All workers		
Collective dose (person-rem)	1,000	1,800 - 4,700
Number of latent cancer fatalities	0.4	0.72 - 1.9

a. Source: Appendix F, Table F-32 and F-60.

Table 8-25. Radiological health impacts to the public from the monitoring period.

Impact	Higher-temperature: Total	Higher-temperature: Maximum annual	Lower-temperature: Total	Lower-temperature: Annual
	Proposed Action			
Dose to public				
Offsite MEI[a] (millirem)	29	0.41	30 - 62	0.59 - 0.89
80-kilometer population (person-rem)	600	8	1,500 - 3,500	11 - 17
Offsite MEI probability of latent cancer fatality	0.000015	2.1×10^{-7}	0.000015 - 0.000031	3×10^{-7} - 4.4×10^{-7}
80-kilometer population number of latent cancer fatalities	0.3	0.004	0.75 - 1.7	0.0057 - 0.0085
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	39	0.62	20 - 100	0.29 - 1.4
80-kilometer population (person-rem)	740	12	2,200 - 5,400	5.6 - 28
Offsite MEI probability of latent cancer fatality	0.000019	3.1×10^{-7}	0.00001 - 0.00005	1.5×10^{-7} - 7.2×10^{-7}
80-kilometer population number of latent cancer fatalities	0.37	0.006	1.1 - 2.7	0.0028 - 0.014

a. MEI = maximally exposed individual.

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Table 8-26. Summary of industrial hazard health and safety impacts to facility workers during closure phase.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	320	340 - 420
Lost workday cases	150	160 - 200
Fatalities	0.15	0.16 - 0.2
Noninvolved worker		
Total recordable cases of injury and illness	51	53 - 62
Lost workday cases	25	26 - 30
Fatalities	0.045	0.047 - 0.054
All workers		
Total recordable cases of injury and illness	370	390 - 480
Lost workday cases	180	190 - 230
Fatalities	0.2	0.21 - 0.25
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	350	400 - 600
Lost workday cases	170	190 - 280
Fatalities	0.17	0.19 - 0.28
Noninvolved worker		
Total recordable cases of injury and illness	54	59 - 82
Lost workday cases	26	29 - 40
Fatalities	0.048	0.052 - 0.072
All workers		
Total recordable cases of injury and illness	400	460 - 680
Lost workday cases	200	220 - 320
Fatalities	0.22	0.24 - 0.35

a. Source: Appendix F, Tables F-38 and F-66.

Industrial Hazards to Workers

Table 8-29 summarizes health and safety impacts to workers from industrial hazards common to the workplace for all phases. The calculated health impacts from industrial hazards common to the workplace would be in the range of 2 to 3 fatalities for Inventory Module 1 or 2. Most of the impacts would come from the operations period. Industrial safety impacts for Module 1 or 2 are about 30 to 40 percent greater than those for the Proposed Action.

Radiological Health

Workers. Table 8-30 summarizes radiological doses and health impacts to workers for the Proposed Action and Inventory Module 1 or 2. It lists these impacts as the likelihood of a latent cancer fatality for the maximally exposed individual worker over a 50-year working career, and as the number of latent cancer fatalities that could occur in the population. The calculated values for latent cancer fatalities for repository workers during the construction, operation and monitoring, and closure phases for Module 1 or 2 are in the range of 6 to 8 fatalities for Module 1 or 2. These are higher than those for the Proposed Action (4 to 7 fatalities) and would be about double those from normal workplace industrial hazards (see Table 8-29).

Most of the total worker radiation dose would be from the receipt and handling of spent nuclear fuel during the operation period. Radiation exposure from inhalation of radon-222 and its decay products by exposure to radiation emanating from the subsurface would also be contributors to the total dose. No other activities in the area were identified that could cause cumulative impacts to repository workers.

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Table 8-27. Summary of radiological health impacts to workers from all activities during closure phase.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	320	340 - 420
Lost workday cases	150	160 - 200
Fatalities	0.15	0.16 - 0.2
Noninvolved worker		
Total recordable cases of injury and illness	51	53 - 62
Lost workday cases	25	26 - 30
Fatalities	0.045	0.047 - 0.054
All workers		
Total recordable cases of injury and illness	370	390 - 480
Lost workday cases	180	190 - 230
Fatalities	0.2	0.21 - 0.25
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	350	400 - 600
Lost workday cases	170	190 - 280
Fatalities	0.17	0.19 - 0.28
Noninvolved worker		
Total recordable cases of injury and illness	54	59 - 82
Lost workday cases	26	29 - 40
Fatalities	0.048	0.052 - 0.072
All workers		
Total recordable cases of injury and illness	400	460 - 680
Lost workday cases	200	220 - 320
Fatalities	0.22	0.24 - 0.35

a. Source: Appendix F, Tables F-39 and F-67.

Table 8-28. Radiological health impacts to the public from the closure phase.

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual	Total	Annual
	Proposed Action			
Dose to public				
Offsite MEI[a] (millirem)	3	0.39	4.3 - 9.4	0.55 - 0.85
80-kilometer population (person-rem)	57	7.4	83 - 180	10 - 16
Offsite MEI probability of latent cancer fatality	1.5×10^{-6}	1.9×10^{-7}	2.2×10^{-6} - 4.7×10^{-6}	2.7×10^{-7} - 4.2×10^{-7}
80-kilometer population number of latent cancer fatalities	0.028	0.0037	0.041 - 0.09	0.0052 - 0.0081
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	4.9	0.57	8.5 - 19	0.83 - 1.4
80-kilometer population (person-rem)	95	11	160 - 360	16 - 26
Offsite MEI probability of latent cancer fatality	2.5×10^{-6}	2.9×10^{-7}	$4.2 \times$ 10-6 - 9.5×10^{-6}	4.2×10^{-7} - 6.9×10^{-7}
80-kilometer population number of latent cancer fatalities	0.047	0.0055	0.081 - 0.18	0.008 - 0.013

a. MEI = maximally exposed individual.

Public. Table 8-31 summarizes radiological doses and health impacts to the public during all phases for the Proposed Action and Inventory Module 1 or 2. The radiological doses and health impacts would result from exposure of the public to naturally occurring radon-222 and decay products released from the subsurface facilities in ventilation exhaust air. The calculated likelihood for Module 1 or 2 that the maximally exposed individual would experience a latent cancer fatality is less than 0.00005. The

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Table 8-29. Summary of industrial hazard health and safety impacts to facility workers during all phases.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature[b]
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	2,200	2,500 - 3,300
Lost workday cases	1,000	1,200 - 1,500
Fatalities	1.5	1.8 - 2.6
Noninvolved worker		
Total recordable cases of injury and illness	470	500 - 720
Lost workday cases	230	250 - 350
Fatalities	0.45	0.48 - 0.68
All workers		
Total recordable cases of injury and illness	2,700	3,000 - 4,000
Lost workday cases	1,200	1,500 - 1,900
Fatalities	2	2.3 - 3.3
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	2,900	3,400 - 4,000
Lost workday cases	1,400	1,600 - 1,900
Fatalities	2.1	2.4 - 3.1
Noninvolved worker		
Total recordable cases of injury and illness	640	690 - 830
Lost workday cases	310	340 - 410
Fatalities	0.61	0.65 - 0.78
All workers		
Total recordable cases of injury and illness	3,500	4,100 - 4,800
Lost workday cases	1,700	1,900 - 2,300
Fatalities	2.7	3.1 - 3.9

a. Source: Appendix F, Tables F-40 and F-68.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because the values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

estimated increase in the number of latent cancer fatalities is less than 2 for the exposed population within about 80 kilometers (50 miles) over the period of more than 100 years of repository activities.

For purposes of comparison, the number of latent cancer fatalities calculated from the public for the Yucca Mountain construction, operation and monitoring, and closure phases for Inventory Module 1 or 2 would be less than 0.75. Statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause (adapted from DIRS 153066-Murphy 2000, p. 83). Assuming this rate would remain unchanged for the estimated population in 2035 of about 76,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 18,000 members of this population would be likely to die from cancer-related causes.

As discussed in Section 8.2.2.2.2, the current operations at the Nevada Test Site resulted in a dose to the maximally exposed individual in 1999 of 0.12 millirem. During that same year, the population dose from Nevada Test Site activities was 0.38 person-rem. Conservatively adding the doses from repository activities to Nevada Test Site activities would result in a dose of 2.3 millirem to the maximally exposed individual and 42 person-rem to the population.

As discussed in the introduction to Section 8.2.7, potential radiological doses from past weapons testing at the Nevada Test Site could result in additional impacts to those residents who were present during that

Table 8-30. Summary of radiological health impacts to workers from all activities during all phases.[a]

Worker group	Operating mode: Higher-temperature	Operating mode: Lower-temperature[b]
	Proposed Action	
Involved worker		
Dose to maximally exposed worker (millirem)	18,000	18,000 - 30,000
Probability of latent cancer fatality	0.0072	0.0072 - 0.012
Collective dose (person-rem)	9,800	11,000 - 17,000
Number of latent cancer fatalities	3.9	4.4 - 6.8
Noninvolved worker		
Dose to maximally exposed worker (millirem)	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072
Collective dose (person-rem)	230	280 - 360
Number of latent cancer fatalities	0.092	0.11 - 0.14
All workers		
Collective dose (person-rem)	10,000	11,000 - 17,000
Number of latent cancer fatalities	4	4.4 - 6.8
	Inventory Module 1 or 2	
Involved worker		
Dose to maximally exposed worker (millirem)	24,000	24,000 - 33,000
Probability of latent cancer fatality	0.0096	0.0096 - 0.013
Collective dose (person-rem)	14,000	16,000 - 20,000
Number of latent cancer fatalities	5.6	6.4 - 8
Noninvolved worker		
Dose to maximally exposed worker (millirem)	2,400	2,400
Probability of latent cancer fatality	0.00096	0.00096
Collective dose (person-rem)	270	330 - 410
Number of latent cancer fatalities	0.11	0.13 - 0.16
All workers		
Collective dose (person-rem)	14,000	16,000 - 20,000
Number of latent cancer fatalities	5.6	6.4 - 8

a. Source: Appendix F, Tables F-41 and F-69.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because the values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

Table 8-31. Summary of radiological health impacts to the public from all project phases.

Impact	Higher-temperature: Total	Higher-temperature: Maximum annual	Lower-temperature[a]: Total	Lower-temperature[a]: Annual
	Proposed Action			
Dose to public				
Offsite MEI[b] (millirem)	31	0.73	44 - 62	1 - 1.3
80-kilometer population (person-rem)	930	14	1,900 - 3,900	20 - 26
Offsite MEI probability of latent cancer fatality	0.000016	3.7×10^{-7}	0.000022 - 0.000031	5.2×10^{-7} - 6.7×10^{-7}
80-kilometer population number of latent cancer fatalities	0.46	0.0071	0.97 - 2	0.010 - 0.013
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	51	0.94	60 - 110	1.3 - 2.2
80-kilometer population (person-rem)	1,300		3,100 - 6,200	5.6 - 42
Offsite MEI probability of latent cancer fatality	0.000026	4.7×10^{-7}	0.00003 - 0.000057	6.7×10^{-7} - 1.1×10^{-6}
80-kilometer population number of latent cancer fatalities	0.65	0.0091	1.5 - 3.1	0.0028 - 0.021

a. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because the values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
b. MEI = maximally exposed individual.

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timeframe. If the maximally exposed individual is assumed to have also been present during the entire time period in which weapons testing occurred, the maximally exposed individual dose listed in Table 8-31 could be increased by as much as 150 millirem. (These doses have been included in Table 8-60.)

8.2.8 ACCIDENTS

Disposal in the proposed repository of the additional spent nuclear fuel and high-level radioactive waste along with the Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in Inventory Module 1 or 2 would result in a very small increase in the estimated risk from accidents described in Chapter 4, Section 4.1.8, for the Proposed Action. The potential hazards and postulated accident scenarios identified and evaluated in Chapter 4, Section 4.1.8, would be the same as those for Module 1 or 2 because there would be no change to the basic repository design or operation. The time required for receipt, packaging, and emplacement of the additional waste would extend from 24 to 38 years, but the probability of an accident scenario (likelihood per year) would be essentially unaffected. The accident scenario consequences evaluated for the Proposed Action would bound those that could occur for Inventory Module 1 or 2 because the spent nuclear fuel and high-level radioactive waste, except the Greater-Than-Class-C waste and the Special-Performance-Assessment-Required waste, would be the same. DOE has not determined the final disposition method for Greater-Than-Class-C and Special-Performance-Assessment-Required waste but, based on the characteristics and expected packaging of these wastes (type and quantity of radionuclides; see Appendix A), the accident scenario consequences calculated in Chapter 4, Section 4.1.8 for spent nuclear fuel and high-level radioactive waste would be bounding. Therefore, substantial cumulative accident impacts would be unlikely for Inventory Module 1 or 2.

The analysis of potential external events in Appendix H considered the potential effects on the Yucca Mountain Repository if there was a decision in the future to resume nuclear weapons testing or from a possible vehicle launch or recovery accident at the proposed VentureStar®/Kistler project. An earlier environmental assessment (DIRS 100136-DOE 1986, all) states that DOE could temporarily suspend underground repository activities during a nuclear weapons test to ensure worker safety. The Department has not decided that such a suspension of work activities at the repository would be necessary at the present time; however, as it finalized the design of the proposed repository, the Department could find it necessary to enact worker safety requirements at the repository site if there was a resumption of nuclear weapons testing. As discussed in Section 8.1.2.2, the Kistler aerospace activity is currently on hold.

In addition, the analysis identified no other Federal, non-Federal, or private action that could affect either the occurrence probability or consequences of the accident scenarios evaluated for the Proposed Action or Inventory Modules.

8.2.9 NOISE

The emplacement of Inventory Module 1 or 2 would have noise levels associated with the construction and operation of the repository similar to those for the Proposed Action. An increase in potential noise impacts from Module 1 or 2 would result only from the increased number of shipments to the site. The expected rate of receipt would be about the same as that for the Proposed Action; therefore, the impact would be an extended period (approximately 14 years) that shipping would continue beyond the Proposed Action.

DOE does not expect other Federal, non-Federal, or private actions in the region to add measurable noise impacts to those of the Proposed Action or Inventory Module 1 or 2 because the other activities are some distance from the proposed repository, and it is unlikely that overall increased noise would result.

8.2.10 AESTHETICS

There would be no impacts for Inventory Module 1 or 2 beyond those described in Chapter 4, Section 4.1.10, because the profile of the repository facility would not be different as a result of implementation of Modules 1 or 2. One action that could add to cumulative aesthetics impacts of the region would be the construction and operation of a proposed wind farm (DIRS 154545-DOE 2001, all) on the Nevada Test Site. The locations being considered for the proposed wind farm are located within the areas of Pahute Mesa and the Shoshone Mountains. The areas under consideration are higher in elevation than the surrounding environs. With the addition of the wind turbine to maximum heights of approximately 430 feet above-ground surface these wind turbines may be visible from the west (especially from mountain ranges west of the Nevada Test Site).

8.2.11 UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to utilities, energy, materials, and site services from the construction, operation and monitoring, and closure of the repository for Inventory Module 1 or 2. The scope of the analysis includes electricity use, fossil-fuel and oil and lubricant consumption, and consumption of construction materials. Chapter 4, Section 4.1.11, evaluates special services such as emergency medical support, fire protection, and security and law enforcement, which would not change for Inventory Module 1 or 2. The material in this section parallels Section 4.1.11, which addresses impacts from the Proposed Action. DOE has considered the other actions described in Section 8.1 to evaluate the potential for cumulative impacts on utilities, energy, materials, and site services. Most of the actions have limited information on their potential cumulative impacts, or the available information indicates that there could be no cumulative impacts. However, one action that would potentially have a cumulative impact is the Alternative Energy Generation Facility (Wind Farm) on the Nevada Test Site, which would increase electrical generating capacity for the region by approximately 600 megawatts, which represents less than 15 percent of the peak power (4,300 megawatts) distributed by Nevada Power in 2000, as described in Chapter 3, Section 3.1.11.2.

To determine the potential impacts of Inventory Module 1 or 2, DOE evaluated the projected uses of electricity, fuel, oils and lubricants and construction materials for each repository phase and compared them to those for the Proposed Action. The following paragraphs describe these evaluations.

Construction

As in the Proposed Action, the major impact during the construction phase for Inventory Module 1 or 2 would be the estimated demand for electric power. The peak demand for electricity for the Proposed Action would be 25 megawatts during construction (Table 8-32). During the construction required for Module 1 or 2, the peak demand for electricity would be about the same (25 megawatts). The tunnel boring machines would account for more than half of the demand for electricity during the 5-year construction phase, but power would also be required to operate ventilation equipment and to support the construction of surface facilities. As for the Proposed Action, the existing electric transmission and distribution system at the Nevada Test Site could not support this increased demand. DOE is evaluating modifications to the site electrical system, as discussed in Chapter 4, Section 4.1.11.

The use of electricity for the higher-temperature operating mode for Inventory Module 1 or 2 would be about 150,000 megawatt-hours during the construction phase, which is about the same as for the Proposed Action (see Table 8-33). For the lower-temperature operating mode the electricity usage ranges from 190,000 to 210,000 megawatt-hours, which is the same as for the Proposed Action. The similarity in numbers between the Proposed Action and the Inventory Modules is due to the similar length of time for construction activities.

Table 8-32. Peak electric power demand (megawatts).

Phase	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Proposed Action		
Construction	25	25
Operation and monitoring		
Operation	47	40 - 54
Monitoring	8	7.8 - 15
Closure	10	10 - 18
Maximum	47	40 - 54
Inventory Module 1 or 2		
Construction	25	25
Operation and monitoring		
Operation	53	44 - 54
Monitoring	11	11 - 15
Closure	14	10 - 18
Maximum	53	44 - 54

Table 8-33. Electricity use (1,000 megawatt-hours).

Phase	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Proposed Action		
Construction	150	190 - 210
Operation and monitoring		
Operation	5,200	5,300 - 9,200
Monitoring	4,800	9,700 - 29,000
Closure	720	790 - 1,300
Totals	***11,000***	***16,000 - 36,000***
Inventory Module 1 or 2		
Construction	150	190 - 200
Operation and monitoring		
Operation	8,200	7,700 - 9,700
Monitoring	6,000	11,000 - 39,000
Closure	1,100	1,300 - 1,600
Totals	***15,000***	***21,000 - 50,000***

The use of liquid fossil fuel during the construction phase would include diesel fuel and fuel oil. The estimated liquid fuel use would be 5.5 to 6 million liters (1.5 to 1.6 million gallons) which would be about the same as for the Proposed Action (see Table 8-34). About 2.6 to 3.5 million liters of oils (primarily hydraulic oil) and lubricants would also be used to support construction as shown in Table 8-35. The usage rate should be well within the regional supply capacity and, therefore, would not result in substantial impacts.

The primary materials needed to support construction would be concrete, steel, and copper. Concrete would be used for liners in the main drifts and ventilation shafts. Concrete also would be used in the construction of the surface facilities. The quantity of concrete required for the surface facilities and initial emplacement drift construction would be about 420,000 to 500,000 cubic meters (550,000 to 650,000 cubic yards). Cement (see Table 8-36) would come from regional suppliers. Sand and gravel needs would be met from materials excavated from the repository or hauled to the repository by local/regional suppliers. As much as 120,000 metric tons (132,000 tons) of steel for a variety of uses including rebar, piping, vent ducts, and track, and 230 metric tons (250 tons) of copper for electrical cable also would be required. These quantities would not be likely to affect the regional supply capacity.

Table 8-34. Fossil-fuel use (million liters).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	5.5	5.5 - 6.0
Operation and monitoring		
Operation	360	360 - 500
Monitoring	2.3	2.6 - 13
Closure	5.2	5.1 - 6.6
Totals	***370***	***380 - 510***
Inventory Module 1 or 2		
Construction	5.4	5.5 - 6.1
Operation and monitoring		
Operation	550	550 - 600
Monitoring	2.1	7 - 22
Closure	7.4	6.1 - 6.9
Totals	***560***	***570 - 620***

Table 8-35. Oils and lubricants (million liters).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	2.6	3.1 - 3.5
Operation and monitoring		
Operation	8.5	9.8 - 18
Monitoring	9	13 - 53
Closure	1.7	1.8 - 3
Totals	***22***	***33 - 71***
Inventory Module 1 or 2		
Construction	2.6	3.1 - 3.5
Operation and monitoring		
Operation	13	16 - 27
Monitoring	9.9	23 - 110
Closure	3.8	2.9 - 3.2
Totals	***30***	***56 - 140***

Table 8-36. Cement use (1,000 metric tons).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	160	190
Operation and monitoring		
Operation	100	150 - 340
Monitoring	0	0
Closure	1.2	1.2 - 1.9
Totals	***250***	***310 - 530***
Inventory Module 1 or 2		
Construction	160	160 - 190
Operation and monitoring		
Operation	260	290 - 890
Monitoring	0	0
Closure	1.9	1.9 - 2.0
Totals	***420***	***480 - 1,100***

Operation and Monitoring

The event that would indicate the start of the operation and monitoring phase would be the beginning of emplacement of spent nuclear fuel and high-level radioactive waste. During this phase the construction of emplacement drifts would continue in parallel with emplacement activities at about the same rate as during the construction phase. As a result, the peak electric power demand would increase to between about 44 and 54 megawatts. The maximum value of 54 megawatts would be about the same as that for the Proposed Action. As was the case for the Proposed Action, DOE would have to upgrade or revise the transmission and distribution system on the Nevada Test Site to meet this demand. However, the upgrade or revision for the Proposed Action would accommodate the similar increase for Inventory Module 1 or 2.

The demand for electricity for Inventory Module 1 or 2 would be well within the regional capacity for power generation. Nevada Power Company, for example, plans to maintain a reserve capacity of about 12 percent. For the beginning of the operation and monitoring phase in 2010, Nevada Power projects a net peak load of about 6,000 megawatts and plans a reserve of about 710 megawatts (DIRS 103413-NPC 1997, Figure 4, p. 9). The repository peak demand of 54 megawatts would be less than 1 percent of the Nevada Power Company planned capacity and about 8 percent of planned reserves. The repository would not affect the regional availability of electric power to any extent.

Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It should range between 360 and 500 million liters (100 and 130 million gallons) during repository operations. The corresponding use of oils and lubricants would be between 23 and 130 million liters (6 and 34 million gallons). The annual usage rates for fuels would be highest during the first half of the operation and monitoring phase (emplacement and continued construction of drifts) and would decrease substantially during the monitoring period (see Table 8-34). The projected annual usage rates of liquid petroleum products would be higher than those for the Proposed Action but would still be within the regional supply capacity.

Additional construction materials would be required to support the continued construction of subsurface facilities for Inventory Module 1 or 2. About 660,000 cubic meters (860,000 cubic yards) of concrete would be required for the flexible design, higher-temperature repository operating mode, and 730,000 to 2,300,000 cubic meters (950,000 to 3,000,000 cubic yards) would be required for the lower-temperature repository operating mode (see Table 8-37). Corresponding amounts of cement that would be obtained regionally are shown in Table 8-36.

Table 8-37. Concrete use (1,000 cubic meters).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	420	490 - 500
Operation and monitoring		
Operation	240	350 - 880
Monitoring	0	0
Closure	3	3 - 5
Totals	***670***	***850 - 1,400***
Inventory Module 1 or 2		
Construction	420	430 - 490
Operation and monitoring		
Operation	660	730 - 2,300
Monitoring	0	0
Closure	5	4 - 5
Totals	***1,100***	***1,200 - 2,800***

The requirement for steel would be between 120,000 and 360,000 metric tons (130,000 and 390,000 tons), and for copper it would be about 200 and 1,100 metric tons (220 and 1,200 tons) (see Tables 8-38 and 8-39). These quantities, while above the Proposed Action, would be unlikely to affect the regional supply capacity because the annual usage rate would be only slightly higher than that for the Proposed Action.

Table 8-38. Steel use (1,000 metric tons).

	Operating mode	
Phase	Higher-temperature	Lower-temperature
Proposed Action		
Construction	100	120
Operation and monitoring		
Operation	62	150 - 180
Monitoring	0	0
Closure	0.03	0.04
Totals	***160***	***270 - 300***
Inventory Module 1 or 2		
Construction	100	100 - 120
Operation and monitoring		
Operation	120	190 - 360
Monitoring	0	0
Closure	0.04	0.04 - 0.07
Totals	***230***	***290 - 480***

Table 8-39. Copper use (1,000 metric tons).

	Operating mode	
Phase	Higher-temperature	Lower-temperature
Proposed Action		
Construction	0.20	0.23
Operation and monitoring		
Operation	0.08	0.24 - 0.6
Monitoring	0	0
Closure	0	0
Totals	***0.30***	***0.50 - 0.86***
Inventory Module 1 or 2		
Construction	0.20	0.16 - 0.23
Operation and monitoring		
Operation	0.20	0.3 - 1.1
Monitoring	0	0
Closure	0	0
Totals	***0.4***	***0.46 - 1.3***

Closure

The peak electric power required during the closure phase for Inventory Module 1 or 2 would be only slightly higher than that for the Proposed Action and would be less than 20 megawatts for all operating modes. This would be much less than the peak levels predicted for the earlier phases, so impacts would be small.

Fossil-fuel use would be between 6.1 million and 7.4 million liters (1.6 million and 2.0 million gallons). A small amount of concrete and steel would be used for closure. An estimated maximum of 5,000 cubic meters (6,500 cubic yards) of concrete would be required for any operating mode. Similarly, an estimated maximum 70 metric tons (77 tons) of steel would be required for closure. The fossil-fuel and material quantities required for closure would not be large and would not result in substantial impacts.

8.2.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

8.2.12.1 Inventory Module 1 or 2 Impacts

Activities for the emplacement of Inventory Module 1 or 2 would generate waste totals beyond the quantities estimated for the Proposed Action (see Chapter 4, Section 4.1.12). The generated waste types and the treatment and disposal of each waste type would be the same as those described for the Proposed Action. The quantities of generated waste are primarily affected by the increase in the amount of spent nuclear fuel and waste emplaced and the subsequent longer operations and monitoring and closure phases. (Table 8-3 lists the difference in time sequences.) Table 4-40 presents the waste types and quantities generated from activities during the construction phase. This table applies to both the Proposed Action and the Inventory Modules because the timeframe and actions are the same during this phase. Table 8-40 lists the waste quantities generated for Inventory Modules 1 and 2 for the operation and monitoring phase. Table 8-41 lists the waste quantities generated for Inventory Modules 1 and 2 for the closure phase.

Table 8-40. Estimated operation and monitoring phase waste quantities.[a]

Waste type	Operating mode	
	Higher-temperature	Lower-temperature
	Inventory Module 1	
Low-level radioactive (cubic meters)a	110,000	110,000 - 230,000
Hazardous (cubic meters)	10,000	9,200 - 16,000
	Inventory Module 2	
Low-level radioactive (cubic meters)	130,000	130,000 - 270,000
Hazardous (cubic meters)	12,000	11,000 - 20,000
	Inventory Module 1 or 2	
Sanitary and industrial solid (cubic meters)	110,000	120,000 - 170,000
Sanitary sewage[b] (million liters)	2,500	3,000 - 3,900
Industrial wastewater (million liters)	1,400	1,400 - 2,200

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

Table 8-41. Estimated closure phase waste quantities.[a]

Waste type	Inventory Module 1 or 2	
	Higher-temperature	Lower-temperature
Low-level radioactive (cubic meters)[b]	3,500	3,200 - 7,100
Hazardous (cubic meters)	1,200	1,100 - 1,800
Sanitary and industrial solid (cubic meters)	10,000	14,000 - 18,000
Sanitary sewage (million liters)[c]	180	240 - 410
Industrial wastewater (million liters)	84	110 - 160
Demolition debris (cubic meters)	220,000	220,000 - 440,000

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. Module 1 is 7,000 cubic meters.
c. To convert liters to gallons, multiply by 0.26418.

Sanitary and industrial solid waste, sanitary sewage, and industrial wastewater would be disposed of in facilities at the repository site. These facilities would be designed to accommodate the additional waste from Inventory Module 1 or 2. However, DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction and demolition debris and sanitary and industrial solid waste. If Nevada Test Site landfills were used, about 360,000 cubic meters (13 million cubic feet) for the higher-temperature operating mode and 640,000 cubic meters (23 million cubic feet) under the lower-temperature operating mode would be disposed of from construction through closure. Disposal of the Proposed Action waste quantities would require the Nevada Test Site landfills to operate past their projected operating lives and to expand as needed (Chapter 4, Section 4.1.12.2). Disposal of the larger waste quantities under Inventory Module 1 or 2 would require the availability of additional disposal capacity in future landfill expansions.

Impacts from the treatment and disposal of hazardous waste off the site would be the same for the Proposed Action and Inventory Module 1 or 2. At present, commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. The National Capacity Assessment Report (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50) indicates that the estimated 20-year (1993 to 2013) available capacity for incineration of solids and liquids at permitted treatment facilities in the western states is about 7 times more than the demand for these services. Moreover, the report indicates that the estimated landfill capacity for hazardous waste disposal is about 50 times the demand. Given the current outlook for the capacity versus demand for hazardous waste treatment and disposal, the treatment and disposal of repository-generated hazardous waste would not present a large cumulative impact.

The Nevada Test Site has an estimated total disposal capacity of 3.7 million cubic meters (130 million cubic feet). The DOE analysis of demand for low-level radioactive waste disposal at the Nevada Test Site through 2070 projects a need for about 1.1 million cubic meters (39 million cubic feet or 30 percent) of the total disposal capacity (DIRS 155856-DOE 2000, Table 4-1). The reserve capacity at the Nevada Test Site is about 2.6 million cubic meters (92 million cubic feet). The disposal of repository-generated waste would require about 5 percent of the reserve capacity for the higher-temperature operating mode and about 5 percent to 9 percent for the lower-temperature operating mode.

Even under the Final Waste Management Programmatic Environmental Impact Statement's (DIRS 101816-DOE 1997, pp. 7-23 and I-39) regional disposal concept, the disposal of repository-generated low-level radioactive waste under the Proposed Action and Inventory Module 1 or 2, cumulatively with other DOE waste generators, would use less than 20 percent of the Nevada Test Site's reserve disposal capacity.

The emplacement of Inventory Module 1 or 2 would require the same types and annual quantities of hazardous materials as the Proposed Action, as described in Chapter 4, Section 4.1.12.3. These materials would be used for the additional years associated with the emplacement of the module inventory. As with the Proposed Action, no cumulative impact would be likely from the procurement and use of hazardous materials at the repository.

8.2.12.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

Waste operations at the Nevada Test Site (disposing of Nevada Test Site-generated waste and accepting waste from other sites in accordance with decisions from the Waste Management Programmatic EIS) could present a cumulative impact. Section 8.2.12.1 discusses the impact on Test Site facilities from disposal of repository waste and waste that is already projected to be disposed of at the Test Site.

If Nevada Test Site landfills are used to dispose of nonrecyclable construction and demolition debris and sanitary and industrial waste, the landfills would be required to operate past their projected operating lives and to expand as needed (the degree of expansion would depend on how much waste was disposed of at the repository facilities).

Low-level waste capacity at the Nevada Test Site is sufficient to accommodate the repository-generated waste and the projected volume of 1.1 million cubic meters of waste from the Test Site, although the facility might have to use some of its reserve capacity to meet the combined need.

8.2.13 ENVIRONMENTAL JUSTICE

As discussed in Chapter 4, Section 4.1.13, the environmental justice analysis brings together the results of all resource and feature analyses to determine (1) if an activity would have substantial environmental impacts and (2) if those substantial impacts would have disproportionately high and adverse human health or environmental effects on minority or low-income populations. DOE determined that cumulative impacts from Inventory Module 1 or 2 along with those expected from other Federal, non-Federal, and private actions would not produce cumulative adverse impacts to any surrounding populations, which would include minority and low-income populations. Evaluation of subsistence lifestyles and cultural values has confirmed that these factors would not change the conclusion that the absence of high and adverse impacts for the general population means there would be no disproportionately high and adverse impacts on minority or low-income communities. No substantial impacts were identified; therefore, cumulative impacts from Inventory Module 1 or 2 and other Federal, non-Federal, and private actions would not cause environmental justice concerns.

DOE recognizes that Native American people living in areas near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that the implementation of the Proposed Action would continue restrictions on access to the site. Chapter 4, Section 4.1.3.4, discusses these views and beliefs.

8.3 Cumulative Long-Term Impacts in the Proposed Yucca Mountain Repository Vicinity

This section describes results from the long-term cumulative impact analysis that DOE conducted for Inventory Modules 1 and 2 (Section 8.3.1) and for past, present, and reasonably foreseeable future actions at the Nevada Test Site, and past actions at the Beatty low-level radioactive waste site (Section 8.3.2).

8.3.1 INVENTORY MODULE 1 OR 2 IMPACTS

The analysis of long-term performance for Inventory Modules 1 and 2 used the same methodology described in Chapter 5 and Appendix I for the Proposed Action to estimate potential human health impacts from radioactive and chemically toxic material releases through waterborne and airborne pathways. Section 8.3.1.1 presents the radioactive and chemically toxic material source terms for Inventory Modules 1 and 2, and Sections 8.3.1.2 and 8.3.1.3 present the results of the analysis for Inventory Modules 1 and 2, respectively.

In addition to long-term human health impacts from radioactive and chemically toxic material releases, the other potential long-term impact identified following repository closure involve biological resources. Though the surface area affected by heat rise would be larger for Inventory Module 1 or 2, the amount of heat per unit area would be constant for a given repository operating mode (lower- or higher-temperature), and, therefore, the small ground surface temperature increase would be the same. Thus, long-term biological effects of Module 1 or 2 from heat generated by waste packages that would potentially raise ground surface temperatures would be the same as those described in Chapter 5, Section 5.9 for the Proposed Action.

8.3.1.1 Radioactive and Chemically Toxic Material Source Terms for Inventory Modules 1 and 2

For calculations of long-term performance impacts, the radioactive material inventory of individual waste packages for commercial spent nuclear fuel, high-level radioactive waste, and DOE spent nuclear fuel under Inventory Modules 1 and 2 would be identical to the radioactive material inventory under the

Proposed Action for the same waste categories. Inventory Module 2 includes an additional waste category for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. This category includes a different category of waste package with its own radioactive material inventory. This waste was simulated with 601 idealized waste packages. The inventory used for each modeled waste package is an averaged radioactive material inventory of each waste category (commercial spent nuclear fuel, DOE spent nuclear fuel, high-level radioactive waste, and Greater-Than-Class-C and Special-Performance-Assessment-Required wastes). More waste packages would be used for Inventory Modules 1 and 2 than for the Proposed Action to accommodate the expanded inventories. Table 8-42 lists the number of waste packages used in the analysis of long-term performance calculations for the Proposed Action and Modules 1 and 2.

Table 8-42. Number of idealized waste packages used in analysis of long-term performance calculations.[a]

Modeled inventory	Commercial SNF[b]	Codisposal (DOE SNF and HLW[c])	GTCC and SPAR[d]	Total
Proposed Action	7,860	3,910	0	11,770
Inventory Module 1	11,754	4,877	0	16,631
Inventory Module 2	11,754	4,877	601	17,232

a. The idealized waste packages in the simulation (model) are based on the inventory abstraction in Appendix I, Section I.3. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the proposed repository would be different.

b. SNF = spent nuclear fuel.

c. HLW = high-level radioactive waste.

d. GTCC = Greater-Than-Class-C; SPAR = Special-Performance-Assessment-Required.

IDEALIZED WASTE PACKAGES

The number of waste packages used in the performance assessment simulations do not exactly match the number of actual waste packages specified in DIRS 150558-CRWMS M&O (2000, Section 6.2).

The TSPA model uses two types of *idealized waste packages* (commercial spent nuclear fuel package and codisposal package), representing the averaged inventory of all the actual waste packages used for a particular waste category.

While the number of idealized waste packages varies from the number of actual waste packages in DIRS 150558-CRWMS M&O (2000, Section 6.2), the total radionuclide inventory represented by all of the idealized waste packages collectively is representative of the total inventory, for the radionuclides analyzed, given in Appendix A of this EIS for the purposes of analysis and long-term performance. *The abstracted inventory is designed to be representative for purposes of analysis of long-term performance and cannot necessarily be used for any other analysis, nor can it be directly compared to any other abstracted inventory used for other analyses in this EIS.*

As listed in Table 8-42, Inventory Module 2 differs from Inventory Module 1 only by the addition of 601 Greater-than-Class-C and Special-Performance-Assessment-Required idealized waste packages. Table 8-43 lists the inventory of the Greater-than-Class-C and Special-Performance-Assessment-Required waste packages under Inventory Module 2.

A screening analysis documented in Appendix I, Section I.6.1, showed that the only chemical materials of concern for the 10,000-year analysis period were those that would be released as the external waste package Alloy-22 layer and the waste package support pallet materials corroded. This is because most waste packages would be intact for more than 10,000 years after closure (the results of the analysis of

Table 8-43. Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes under Inventory Module 2.[a]

Isotope	Inventory
Actinium-227	0
Americium-241	40
Americium-243	0.00151
Carbon-14	28.9
Cesium-137	771
Iodine-129	0.000705
Nickel-63	0
Neptunium-237	0
Protactinium-231	0
Lead-210	0
Plutnium-238	1.56
Plutonium-239	2,860
Plutonium-240	0.0123
Plutonium-241	0.0207
Plutonium-242	0.00614
Radium-226	0.0504
Radium-228	0
Strontium-90	0.82
Technetium-99	568
Thorium-229	0
Thorium-230	0
Thorium-231	0
Uranium-232	0.00000287
Uranium-233	0.00419
Uranium-234	0
Uranium-235	0
Uranium-236	0

a. The idealized waste packages in the simulation (model) are based on the inventory abstraction in Appendix I, Section I.3. While the total inventory is represented by the material in idealized waste packages, the actual number of waste packages emplaced in the proposed repository would be different.

long-term performance for radionuclides described in Appendix I, Section I.5, show that, at most, only three waste packages would be breached before 10,000 years, due to improper heat treatment, under the Proposed Action). Therefore, accounting for the quantities of materials in the engineered barrier system, but not in the waste packages, and accounting for toxicity to humans, the only chemical materials of concern would be chromium, nickel, molybdenum, and vanadium. The inventories of these chemical materials in the engineered barrier system for the Proposed Action and Inventory Modules 1 and 2 are listed in Table 8-44. These are essentially the only inventories available for mobilization and transport within 10,000 years after closure; the inventories of chemical materials in the waste packages would not begin to degrade until waste package failure. Further information on the inventory of chemical materials of concern is provided in Appendix I, Section I.3.

The only radionuclide that would have a relatively large inventory and a potential for gas transport is carbon-14. Iodine-129 can exist in a gas phase, but it is highly soluble and, therefore, would be likely to dissolve in groundwater rather than migrate as a gas. Radon-222 is a gas, but would decay to a solid isotope before escaping from the repository region (see Appendix I, Section I.7.3). After the carbon-14 escaped from the waste package, it could flow through the fractured and porous rock in the form of carbon dioxide. About 2 percent of the carbon-14 in commercial spent nuclear fuel is in gas in the space (or gap) between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92). There are 1.37 grams of carbon-14 in an abstracted commercial spent nuclear fuel waste package (see Appendix I, Table I-5). This represents 6.11 curies per waste package. Since 2 percent of the total is gaseous, the gaseous inventory consists of 0.122 curie of carbon-14 per commercial spent nuclear fuel waste package. There would be additional carbon-14 activity associated with Inventory Module 2, in relation to Module 1, resulting from neutron irradiation of the core shroud metal. The carbon-14 would be unlikely to be present as gaseous carbon dioxide that could be released to the environment and is therefore not included in Table 8-45.

Table 8-44. Total quantities of waterborne chemicals of concern in the engineered barrier system under the Proposed Action and Inventory Modules 1 and 2 (kilograms).[a,b]

Modeled inventory	Chromium	Molybdenum	Nickel	Vanadium
Proposed Action	23,735,000	17,307,000	60,797,000	377,600
Inventory Module 1	34,695,000	25,301,000	88,879,000	552,000
Inventory Module 2	34,951,000	25,490,000	89,545,000	556,000

a. To convert kilograms to pounds, multiply by 2.2046.
b. See screening analysis in Appendix I, Section I.3.2.

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Table 8-45. Total **gaseous** carbon-14 in the repository from commercial spent nuclear fuel for the Proposed Action and Inventory Modules 1 and 2 (curies).

Modeled inventory	Quantity[a]
Proposed Action	959
Inventory Module 1	1,430
Inventory Module 2	1,430

a. Based on 0.122 curies of carbon-14 per commercial spent nuclear fuel waste package.

8.3.1.2 Impacts for Inventory Module 1

The human-health impacts from Inventory Module 1 for radioactive materials and chemically toxic materials are discussed in this section.

8.3.1.2.1 *Waterborne Radioactive Material Impacts*

The DOE used the modeling methods described for the Proposed Action in Chapter 5 (and in greater detail in Appendix I) to calculate the impacts both for an individual and the local population resulting from groundwater releases of radioactive material for 10,000 years and 1 million years following repository closure for Inventory Module 1.

8.3.1.2.1.1 Higher-Temperature Operating Mode. Table 8-46 lists the estimated impacts for an individual for the higher-temperature operating mode under the Proposed Action and Inventory Module 1. The peak annual individual dose for the first 10,000 years shows slightly higher values for the mean and 95th percentile of the Proposed Action than for Module 1. Because Module 1 has a higher inventory, this would seem like an incorrect trend. However, note that in the first 10,000 years releases are dominated by at most about 3 waste package failures due to a manufacturing defect (improper heat treatment). Thus, the release is essentially insensitive to inventory and the differences in Table 8-46 between the Proposed Action and Module 1 are merely the result of slightly different statistical outcomes in the 300 simulations.

Table 8-46. Impacts for an individual from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

		Mean			95th-percentile		
Modeled inventory	Individual	Peak annual individual dose (millirem)	Time of peak (years)	Probability of a LCF[a]	Peak annual individual dose (millirem)	Time of peak (years)	Probability of a LCF[a]
Proposed Action	At RMEI location[b]	0.00002[c]	4,900	6×10^{-10}	0.0001[d]	4,900	4×10^{-9}
	At 30 kilometers[e]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
	At discharge location[h]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
Inventory Module 1	At RMEI location[b]	0.00003[c]	4,900	1×10^{-9}	0.002[d]	4,100	6×10^{-9}
	At 30 kilometers[d]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
	At discharge location[h]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0

a. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).
b. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository. The maximum allowable peak of the mean annual individual dose for 10,000 years at this distance is 15 millirem.
c. Based on 300 simulations of total system performance, using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. To convert kilometers to miles, multiply by 0.62137.
f. Values would be lower than the small values computed for the RMEI location.
g. NC = not calculated (peak time would be greater than time given for the RMEI location).
h. 60 kilometers (37 miles) at Franklin Lake Playa.

Table 8-47 lists the impacts to the population during the first 10,000 years after repository closure for both the Proposed Action and Inventory Module 1 for the higher-temperature operating mode. These impacts were calculated on the same population basis used for the Proposed Action calculations presented in Chapter 5, that is a population size was based on the projected population numbers for 2035 in Figure 3-25 in Chapter 3. For these calculations, the analysis assumed that no contaminated groundwater

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Table 8-47. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.[a]

		Mean		95th-percentile	
Modeled inventory	Case	Population dose (person-rem)	Population LCFs[b]	Population dose (person-rem)	Population LCFs[b]
Proposed Action	Peak 70-year lifetime	0.006	0.000003	0.04	0.00002
	Integrated over 10,000 years	0.5	0.0002	0.6	0.0003
Inventory Module 1	Peak 70-year lifetime	0.01	0.000005	0.06	0.00003
	Integrated over 10,000 years	0.7	0.0003	0.8	0.0004

a. Based on 300 simulations of total system performance for each location, using random samples of uncertain parameters.
b. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).

would reach populations in any regions to the north of Yucca Mountain. Therefore, populations in the sectors north of the due east and due west sectors were not considered to be exposed.

- 47 people would be exposed at the Reasonably Maximally Exposed Individual (RMEI) location [approximately 18 kilometers (11 miles)] downgradient from the repository [includes sectors from 12 to 28 kilometers (7 to 27 miles)].

- 4,200 people would be exposed at about 30 kilometers (19 miles) downgradient from the potential repository [includes sectors from 28 to 44 kilometers (17 to 27 miles)].

- 69,500 people would be exposed at the discharge location, about 60 kilometers (37 miles) downgradient of the potential repository [includes sectors from 44 to 80 kilometers (27 to 50 miles)].

Thus, approximately 74,000 people would be exposed to contaminated groundwater. This stylized population dose analysis assumed that people would continue to live in the locations being used at present. This assumption is consistent with the recommendation made by the National Academy of Sciences (DIRS 100018-National Research Council 1995, all) because it is impossible to make accurate predictions of future lifestyles and residence locations far into the future.

The population impacts would be greater than the impacts for the Proposed Action under the higher-temperature operating mode. For example, the population dose in the 70-year period of maximum impacts would be about 25 percent greater for Module 1 than for the Proposed Action at the mean level and the same 70-year period.

The values in Table 8-47 include a scaling factor for water use. The performance assessment transport model calculated the annual individual dose assuming the radionuclides dissolved in water that flowed through the unsaturated zone of Yucca Mountain would mix in an average of 2.4 million cubic meters (1,940 acre-feet) (DIRS 155950-BSC 2001, p. 13-42) per year in the saturated zone aquifer. This compares to an annual water use in the Amargosa Valley of about 17.1 million cubic meters (13,900 acre-feet) (DIRS 155950-BSC 2001, p. 13-42). The analysis diluted the concentration of the nuclides in the 2.4 million cubic meters of water throughout the 17.1 million cubic meters of water prior to calculating the population dose.

Table 8-48 lists the peak annual individual dose and time of peak for 1 million years after repository closure for both Inventory Module 1 and the Proposed Action for the higher-temperature operating mode. The impacts would follow the same pattern as those for the first 10,000 years after repository closure listed in Table 8-47, with the impacts for Module 1 about 60 percent greater than those for the Proposed Action.

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Table 8-48. Impacts to an individual from groundwater releases of radionuclides for 1 million years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

		Mean		95th-Percentile	
Modeled inventory	Individual	Peak annual individual dose (millirem)	Time of peak (years)	Peak annual individual dose (millirem)	Time of peak (years)
Proposed Action	At RMEI location[a]	150[b]	480,000	620[c]	410,000
	At 30 kilometers[d]	100[e]	NC[f]	420[e]	NC[f]
	At discharge location[g]	59[e]	NC[f]	240[e]	NC[f]
Inventory Module 1	At RMEI location[a]	240[b]	480,000	980[c]	480,000
	At 30 kilometers[d]	160[e]	NC[f]	660[e]	NC[f]
	At discharge location[g]	90[e]	NC[f]	450[e]	NC[f]

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Based on 300 simulations of total system performance for each location, using random samples of uncertain parameters.
c. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
d. To convert kilometers to miles, multiply by 0.62137.
e. Estimated using scale factors as described in Chapter 5, Section 5.4.1.
f. NC = not calculated (peak time would be greater than time given for the RMEI location).
g. 60 kilometers (37 miles) at Franklin Lake Playa.

WHY ARE THE MEAN IMPACTS SOMETIMES HIGHER THAN THE 95TH-PERCENTILE IMPACTS?

The *mean* impact is the arithmetic average of the 300 impact results from simulations of total-system performance. The mean is not the same as the 50th-percentile value (the 50th-percentile value is called the *median*) if the distribution is *skewed*.

The performance results reported in this EIS come from highly skewed distributions. In this context, *skewed* indicates that there are a few impact estimates that are much larger than the rest of the impacts. When a large value is added to a group of small values, the large value dominates the calculation of the mean. The simulations reported in this EIS have mean impacts that are occasionally above the 90th-percentile and occasionally above the 95th percentile.

With respect to groundwater protection standards set forth in 40 CFR Part 197.30, both the mean and the 95th percentile estimated levels during the 10,000-year regulatory period are hundreds of thousands of times less than the regulatory limits (see Table 8-49) for both the Proposed Action and Inventory Module 1.

8.3.1.2.1.2 Lower-Temperature Operating Mode. Impacts were not calculated for the lower-temperature operating mode under Inventory Module 1 or 2 because of the lack of differentiation between higher-temperature and lower-temperature operating modes under the Proposed Action (see Chapter 5). Comparison of the mean individual dose history at the RMEI location for the lower- and higher-temperature operating modes is shown in Figure 8-4. For the Proposed Action, the individual dose for the lower-temperature operating mode at a given location would be about the same as that for the higher-temperature operating mode, with the long-term peak slightly greater for the higher-temperature operating mode. Calculations for Inventory Module 1 produce a similar response. Given the similarity of impacts, and that the lower-temperature operating mode impacts are generally bounded by the higher-temperature operating mode impacts, it was deemed unnecessary to perform detailed simulations for the lower-temperature operating mode under Inventory Module 1. The results would be similar to, but less than, those for the higher-temperature operating mode under Inventory Module 1, as reported in Section 8.3.1.2.1.1.

Table 8-49. Comparison of nominal scenario long-term consequences at the RMEI location[a] to groundwater protection standards during 10,000 years following repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

Modeled inventory	Radionuclide or type of radiation emitted	EPA Limit[b]	Mean peak[c]	95th-percentile peak[d]
Proposed Action	Combined radium-226 and radium-228,[e] picocuries per year	5	1.0 (1×10^{-11})[f]	1.0 (2×10^{-11})
	Gross alpha activity (including radium-226 but excluding radon and uranium),[e] picocuries per year	15	0.4 (2×10^{-8})	0.4 (1×10^{-8})
	Combined beta and photon emitting radionuclides,[g] millirem per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume	4	2×10^{-5}	1×10^{-4}
Inventory Module 1	Combined radium-226 and radium-228,[e] picocuries per year	5	1.0 (3×10^{-10})	1.0 (3×10^{-11})
	Gross alpha activity (including radium-226 but excluding radon and uranium),[e] picocuries per year	15	0.4 (3×10^{-8})	0.4 (4×10^{-8})
	Combined beta and photon emitting radionuclides,[g] millirem per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume	4	3×10^{-5}	2×10^{-4}

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is located approximately 18 kilometers (11 miles) downgradient from the repository.
b. Environmental Protection Agency limits set forth in 40 CFR Part 197.30.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. Includes natural background radiation.
f. Value in parentheses is the incremental increase over background radiation that would be attributable to the potential repository.
g. This represents a bounding (overestimate) of the maximum dose to any organ because the different radionuclides would affect different organs preferentially.

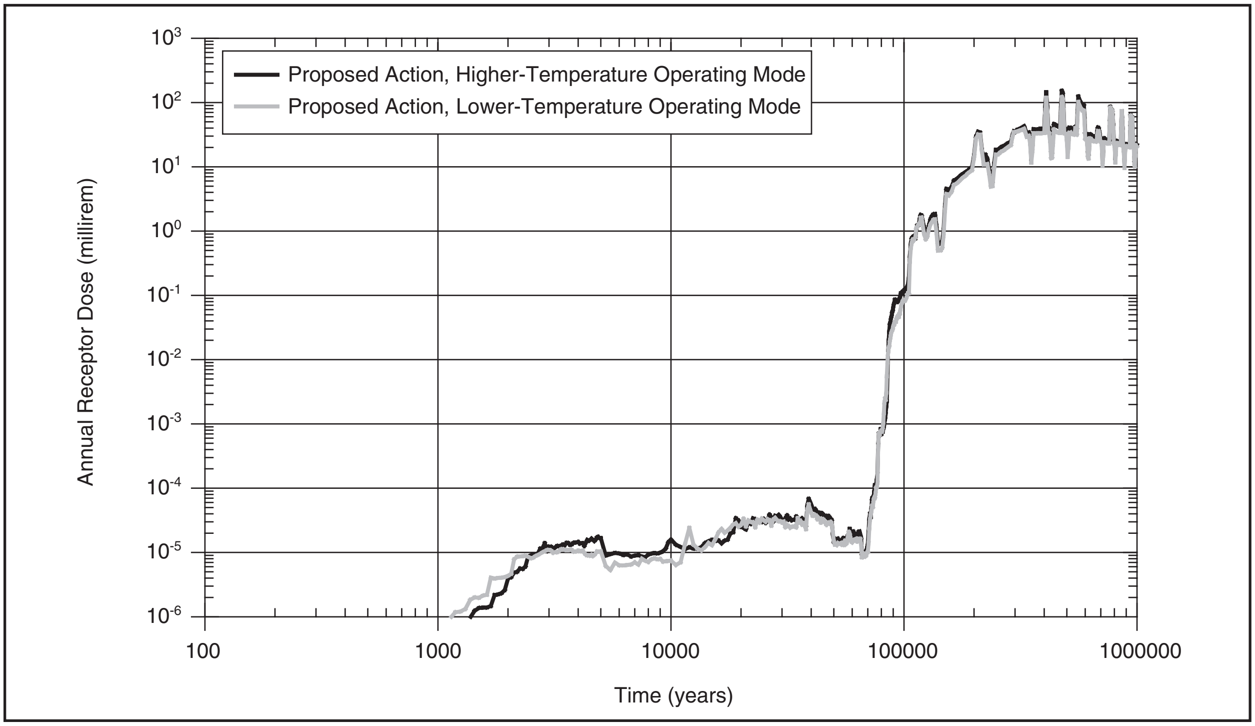

Figure 8-4. Comparison of mean annual individual dose (based on 300 simulations of total system performance, each using random samples of uncertain parameters) at the RMEI location for the higher- and lower-temperature operating modes. (Note use of logarithmic scale for both axes.)

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8.3.1.2.2 *Waterborne Chemically Toxic Material Impacts*

A number of nonradioactive materials that DOE would place in the repository are hazardous to human health at high concentrations in water. This section examines the consequences to individuals in the Amargosa Desert from releases of these nonradioactive materials under Inventory Module 1.

The inventory of chemically toxic materials that would be emplaced in the repository under the Proposed Action is identified by element in Appendix I, Section I.3. Based on this inventory, a screening analysis (described in Appendix I, Section I.6.1) identified which of the chemically toxic materials might pose a risk to human health. Only chromium, molybdenum, nickel, and vanadium were identified as potentially posing such a risk, and these elements were further evaluated in a bounding consequence analysis, as described in Appendix I, Section I.6.2. The analysis was performed under the conservative assumption that all chromium dissolves in hexavalent form. The results of the bounding analysis are summarized for both the Proposed Action and Inventory Module 1 in Table 8-50. In some cases a Maximum Containment Level or Maximum Contaminant Level Goal was available for comparison to the calculated concentration. In other cases, only an Oral Reference Dose was available. The Oral Reference Dose can be compared to intake that would result for a 70-kilogram (154-pound) person drinking 2 liters (0.53 gallon) of water per day. More detail on these comparative measures can be found in Chapter 5, Section 5.6, and Appendix I, Section I.6.2.5.

Table 8-50. Peak concentration of waterborne chemical materials released during 10,000 years after closure estimated using bounding calculations for the Proposed Action and Inventory Module.

Modeled inventory	Material	Estimated concentration in well water (milligram per liter)	Maximum Contaminant Level Goal (milligram per liter)	Estimated intake rate for a 70-kilogram person (milligram per kilogram per day)	Oral Reference Dose (milligram per kilogram per day)
Proposed Action	Chromium (VI)	0.01	0.1[a]	0.0004	0.005[b]
	Molybdenum	0.009	NA[c]	0.0003	0.005[d]
	Nickel	0.04	NA	0.001	0.02[e]
	Vanadium	0.0002	NA	0.000006	0.007[f]
Inventory Module 1	Chromium (VI)	0.02	0.1[a]	0.0006	0.005[b]
	Molybdenum	0.01	NA	0.0004	0.005[d]
	Nickel	0.05	NA	0.002	0.02[e]
	Vanadium	0.0003	NA	0.000009	0.007[f]

a. 40 CFR 191.51.
b. DIRS 148224-EPA (1999, all).
c. NA = not available.
d. DIRS 148228-EPA (1999, all).
e. DIRS 148229-EPA (1999, all).
f. DIRS 103705-EPA (1997, all).

Because the bounding concentration of chromium, molybdenum, nickel, and vanadium in well water is calculated to be below the Maximum Contaminant Level Goal or yield intakes well below the Oral Reference Dose for Inventory Module 1, there is no further need to refine the calculation to account for physical processes that would limit mobilization of this material or delay or dilute it during transport in the geosphere.

8.3.1.2.3 *Atmospheric Radioactive Material Impacts*

Using the analysis methods described in Chapter 5, Section 5.5, DOE estimated the impacts of carbon-14 releases to the atmosphere within 10,000 years past closure for Inventory Module 1. As explained in Appendix I, Section I.7.1, the maximum release rate to the ground surface for this period is the same for both Inventory Modules 1 and 2 as for the Proposed Action. Therefore, there would be no incremental atmospheric radioactive material impacts for Inventory Module 1 for the Proposed Action.

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8.3.1.3 INCREMENTAL IMPACTS FOR INVENTORY MODULE 2

DOE addressed the long-term consequences from Inventory Module 2 by analyzing the effects of disposing waste packages containing Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in addition to the material in Inventory Module 1. Table 8-43 lists the average inventory of the additional waste packages containing Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. The following sections discuss these impacts in terms of waterborne radioactive releases, chemically toxic materials waterborne release, and atmospheric radioactive material releases.

8.3.1.3.1 *Waterborne Radioactive Material Impacts*

The addition of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes is the only difference between Inventory Modules 1 and 2. Inventory Module 2 was modeled as an incremental inventory; specifying only the Greater-Than-Class-C and Special-Performance- Assessment-Required waste as the radionuclide inventory. The results of the incremental inventory simulations constitute the additional impacts of Inventory Module 2 over those of Module 1. In addition, they represent the dose attributable solely to the Greater-Than-Class-C and Special- Performance-Assessment-Required waste.

Table 8-51 lists the incremental consequences for an individual from the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in Inventory Module 2 during 10,000 years and 1 million years following repository closure. Peak impacts from waterborne radioactive materials for Module 2 would be less than 1 percent higher for 1,000,000 years after repository closure. For the first 10,000 years following the repository closure, the Module 2 impact would remain very small (mean annual individual dose of 0.0007 millirem, compared to the Environmental Protection Agency standard of 15 millirem for this period as defined in 40 CFR Part 197).

Table 8-51. Incremental increase (millirem) in mean peak individual annual dose at the RMEI location[a] under Inventory Module 2 over the mean peak individual annual dose under Inventory Module 1 during 10,000 and 1 million years after repository closure.

Postclosure period	Incremental Increase[b]
10,000 years	0.0007
1,000,000 years	0.3

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository.

b. Based on 300 simulations each for Inventory Modules 1 and 2 using random samples of uncertain parameters.

8.3.1.3.2 *Waterborne Chemically Toxic Material Impacts*

A number of nonradioactive materials that DOE would place in the repository are hazardous to human health at high concentrations in water. This section examines the consequences to individuals in the Amargosa Desert from releases of these nonradioactive materials under Inventory Module 2.

The inventory of chemically toxic materials that would be emplaced in the repository under the Proposed Action is identified by element in Appendix I, Section I.3. Based on this inventory, a screening analysis (described in Appendix I, Section I.6.1.) identified which of the chemically toxic materials could pose a risk to human health. Only chromium, molybdenum, nickel, and vanadium were identified as posing such a risk, and these elements were further evaluated in a bounding consequence analysis, as described in Appendix I, Section I.6.2. The results of the bounding analysis are summarized for both the Proposed Action and Inventory Module 2 in Table 8-52. In some cases a Maximum Contaminant Level Goal was available for comparison to the calculated concentration. In other cases, only an Oral Reference Dose was available. The Oral Reference Dose can be compared to the intake that would result for a 70-kilogram (154-pound) person drinking 2 liters (0.53 gallon) of water per day. More detail on these comparative measures can be found in Chapter 5, Section 5.6, and Appendix I, Section I.6.2.5.

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Table 8-52. Peak concentration of waterborne chemical materials released during 10,000 years after closure estimated using bounding calculations for the Proposed Action and Inventory Module 2.

Modeled inventory	Material	Estimated concentration in well water (milligram per liter[a])	Maximum Contaminant Level Goal (milligram per liter)	Estimated intake rate for a 70-kilogram person (milligram per kilogram per day)	Oral Reference Dose (milligram per kilogram per day)
Proposed Action	Chromium (VI)	0.01	0.1[a]	0.0004	0.005[b]
	Molybdenum	0.009	NA[c]	0.0003	0.005[d]
	Nickel	0.04	NA	0.001	0.02[e]
	Vanadium	0.0002	NA	0.000006	0.007[f]
Inventory Module 2	Chromium (VI)	0.02	0.1	0.0006	0.005[b]
	Molybdenum	0.01	NA	0.0004	0.005[d]
	Nickel	0.06	NA	0.002	0.02[e]
	Vanadium	0.0003	NA	0.00001	0.007[f]

a. 40 CFR 191.51.
b. DIRS 148224-EPA (1999, all).
c. NA = not available.
d. DIRS 148228-EPA (1999, all).
e. DIRS 148229-EPA (1999, all).
f. DIRS 103705-EPA (1997, all).

Because the bounding concentration of chromium, molybdenum, nickel, and vanadium in well water is calculated to be below the Maximum Containment Level Goal or yield intakes well below the Oral Reference Dose for Inventory Module 2, there is no further need to refine the calculation to account for physical processes that would limit mobilization of this material or delay or dilute it during transport in the geosphere.

The incremental (that is, the increase in) consequences for an individual from the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in Inventory Module 2 over Inventory Module 1 during 10,000 years and 1 million years following repository closure is 4 percent for all four waterborne chemical materials of concern (chromium, molybdenum, nickel, and vanadium).

8.3.1.3.3 *Atmospheric Radioactive Material Impacts*

There would be no incremental impact for airborne carbon-14 releases for Inventory Module 2. None of the additional waste packages would contain a waste form in which carbon-14 would exist in gaseous form (that is, as carbon dioxide). As for the Proposed Action and Inventory Module 1, radon-222 would be released as a gas but would decay to a solid isotope before escaping from the repository region (see Appendix I, Section I.7.3).

8.3.2 CUMULATIVE IMPACTS FROM OTHER FEDERAL, NON-FEDERAL, AND PRIVATE ACTIONS

This section discusses potential cumulative impacts from other Federal, non-Federal, and private actions that could contribute to doses at the locations considered in the performance assessment of the Yucca Mountain Repository. The actions identified with the potential for long-term cumulative impacts are past, present, and reasonably future actions at the Nevada Test Site and past actions at the low-level radioactive waste disposal facility near Beatty, Nevada.

8.3.2.1 Past, Present, and Reasonably Foreseeable Future Actions at the Nevada Test Site

Historically, the primary mission of the Nevada Test Site was to conduct nuclear weapons tests. Nuclear weapons testing and other activities have resulted in radioactive contamination and have the potential for radioactive and nonradioactive contamination of some areas of the Nevada Test Site. These areas and the associated contamination and the potential for contamination were evaluated for potential cumulative impacts with postclosure impacts from the proposed Yucca Mountain Repository. This section discusses these Nevada Test Site activities, the locations where these activities occurred, and the potential for cumulative long-term impacts with the repository.

Unless otherwise identified, DOE derived the information in this section from the Nevada Test Site Final EIS (DIRS 101811-DOE 1996, all). The Yucca Mountain site is in the southwestern portion of the Nevada Test Site along its western boundary, as shown in Figure 8-2.

At the Nevada Test Site, seven categories of activities have resulted in radioactive contamination or have the potential to result in radioactive and nonradioactive contamination:

1. *Atmospheric Weapons Testing.* One hundred atmospheric detonations occurred before the signing of the Limited Test Ban Treaty in August 1963. Atmospheric tests included detonations at ground level, from towers or balloons, or from airdrops.

2. *Underground Nuclear Testing.* Approximately 800 underground nuclear tests have occurred at the Nevada Test Site. Chapter 3, Figure 3-2 shows the locations of these tests in relation to Yucca Mountain. They included deep underground tests to study weapons effects, designs, safety, and reliability, and shallow underground tests to study the peaceful application of nuclear devices for cratering.

3. *Safety Tests.* Between 1954 and 1963, 16 above-ground tests studied the vulnerability of weapons designs to possible accident scenarios.

4. *Nuclear Rocket Development Station.* Twenty-six experimental tests of reactors, nuclear engines, ramjets, and nuclear furnaces occurred between 1959 and 1973. Figure 8-3 shows the location of the Nuclear Rocket Development Station.

5. *Shallow Land Radioactive Waste Disposal.* DOE disposed of some radioactive waste generated during testing in shallow cells, pits, and trenches. Because of the significant thickness of alluvial material and high mean annual temperatures and low precipitation under the current climate regime, downward advection of groundwater to the water table is highly unlikely. Therefore, shallow burial continues to be an important waste disposal activity at the Nevada Test Site (DIRS 155159-REECo, 1994, all; DIRS 108774-Tyler et al. 1996, all).

Section 8.3.2.1.3 discusses present and potential future low-level radioactive waste disposal activities.

6. *Crater Disposal.* DOE disposed of contaminated soils and equipment collected during the decontamination of atmospheric testing areas and the consolidation of radioactively contaminated structures, and other bulk wastes, in subsidence craters at Yucca Flat in Area 3. Figure 8-3 shows the location of Area 3 on the Nevada Test Site.

7. *Greater Confinement Disposal.* In 1981, Greater Confinement Disposal began at Area 5 for low-level radioactive wastes not suitable for shallow land disposal. This waste includes some transuranic radionuclides. Figure 8-3 shows the location of Area 5 on the Nevada Test Site.

Table 8-53 lists the approximate inventory for each of these categories. Atmospheric testing, shallow underground testing, safety testing, and nuclear rocket development all resulted in a small (less-than-40-curie) source term, which would not contribute substantially to cumulative impacts. Additionally, the inventories represented by crater disposal and shallow-land disposal were determined to not be important to cumulative impact considerations. Only the deep underground testing and greater confinement

Table 8-53. Summary of radioactivity on the Nevada Test Site (January 1996).[a]

Source	Area	Environmental media	Major known isotopes or wastes	Depth range	Approximate inventory (curies)
Atmospheric weapons testing	Aboveground nuclear weapon proving area	Surficial soils and test structures	Americium, cesium, cobalt, plutonium, europium, strontium	At land surface	20
Underground testing: shallow underground tests	Underground nuclear testing areas	Soils and alluvium	Americium, cesium, cobalt, europium, plutonium, strontium	Less than 61 meters[b]	1 at land surface; unknown at depth
Underground testing: deep underground tests	Underground nuclear testing areas	Soils, alluvium, and consolidated rock	Tritium, fission, and activation products	Typically less than 640 meters, but might be deeper	130 million[c]
Safety tests	Aboveground experimental areas	Surficial soils	Americium, cesium, cobalt, plutonium, strontium	Less than 0.9 meter	35
Nuclear rocket development area	Nuclear rocket motor, reactor, and furnace testing area	Surficial soils	Cesium, strontium	Less than 3 meters	1
Shallow land disposal	Waste disposal landfills	Soils and alluvium	Dry-packaged low-level and mixed wastes	Less than 9 meters	500,000[d,e]
Crater disposal	Test-induced subsidence crater with sidewalls, cover, and drainage	Soils and alluvium	Bulk contaminated soils and equipment	Less than 30 meters	1,250[d,f]
Greater confinement disposal	Monitored underground waste disposal	Soils and alluvium	Tritium, americium	37 meters	9.3 million[d,g]

a. Source: DIRS 101811-DOE (1996, p. 4-6). This table uses information and terminology from that document and is for information purposes only.
b. To convert meters to feet, multiply by 3.2808.
c. Source: DIRS 157116-Bowen et al. (2001, Table V, p. 21)
d. Inventory at time of disposal (not corrected for decay).
e. Inventory does not include prospective future low-level radioactive and mixed waste disposal (see Section 8.3.2.1.3).
f. Volume of waste considered for inventory was approximately 205,000 cubic meters (7.25 million cubic feet).
g. Volume of waste considered for inventory was approximately 300 cubic meters (10,000 cubic feet).

disposal categories represent substantial inventories that could, when combined with the repository inventory, potentially result in increased cumulative impacts.

8.3.2.1.1 *Underground Nuclear Testing*

The United States began a moratorium on the explosive testing of nuclear weapons in October 1992. As discussed in the Nevada Test Site EIS (DIRS 101811-DOE 1996), however, other weapons testing continues at the Test Site, including dynamic, hydrodynamic, and explosive tests. These tests are necessary for the continued assurance of the nuclear arsenal but do not result in nuclear explosions like those that were common during the Cold War. Environmental contamination is due largely to past weapons testing and not to the current limited activities at the Test Site. Although there are potential past and present impacts of the explosive testing of nuclear weapons, the long-lived radionuclides that such testing deposited far underground could pose future impacts, which this section evaluates.

As of September 23, 1992, the estimated total radionuclide source term for all tests was about 130 million curies (DIRS 157116-Bowen et al. 2001, Table V, p. 21). Because these radionuclides are either in or close to the water table and therefore subject to dissolution and possible transport by groundwater, they are referred to as the hydrologic source term. This source term represents the remaining radioisotopes (as of September 23, 1992) that could be available to the groundwater regime. However, because of the existence of multiple, complex migration pathways and limited characterization data, there is considerable uncertainty concerning the actual hydrologic source term. In recent years, the drilling of new characterization wells and the retrofitting of existing boreholes and wells have provided valuable new data that are now being integrated into the overall database so new evaluations can be made. These studies and planned future studies will help reduce the current levels of uncertainty concerning the quantity of radionuclides available for groundwater transport as well as uncertainty concerning both the mechanisms and consequences of radionuclide transport by groundwater flow at the Nevada Test Site. Testing with subcritical assemblies since 1994 has added quantities of material that are very small compared to the historical testing. Thus, the Department has based its analysis on the much larger inventory from historical testing (DIRS 156758-Crowe 2001, all).

There is recent evidence of plutonium migration from one underground test. Groundwater monitoring results indicate that plutonium has migrated about 1.3 kilometers (0.8 mile), possibly facilitated by the movement of very small and relatively mobile particles called *colloids* in the groundwater (DIRS 103282-Kersting et al. 1999, p. 59). No radioactive contamination attributable to underground tests has been detected in monitoring wells off the Nevada Test Site. DOE is conducting further monitoring and research to study these and other potential radionuclide migration phenomenon.

The above information indicates that groundwater could transport radionuclides from underground nuclear tests at the Nevada Test Site. This transport could result in releases from underground testing at the sites analyzed for releases from the proposed repository. DOE did not make long-term performance assessment calculations for the underground testing inventory with the same rigor as the analyses for the repository, and there is much uncertainty related to the hydrogeologic system. Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance, including the waste package design, and improve operational safety and efficiency. The result of the design evolution process was the development of the Science and Engineering Report flexible design (DIRS 153849-DOE 2001, all). In addition, DOE has continued technical development of the Total System Performance Assessment since the publication of the Draft EIS, including further site characterization, improvements to the engineered system design, system performance assessment calculations, and quality assurance and validation of results. These efforts have resulted in an updated performance assessment referred to as the Total System Performance Assessment-Site Recommendation (TSPA-Site Recommendation; DIRS 153246-CRWMS M&O 2000). The results of this analysis for long-term impacts from the Yucca Mountain Repository are reported in Chapter 5 of this Final EIS. The TSPA-Site Recommendation evaluated the long-term performance of the Science and Engineering Report flexible design and included the best available information related to contaminant fate and transport. The results for the groundwater impacts from the repository in this analysis are substantially lower than reported in the Draft EIS. However, an update of this simplified scaling analysis used to estimate the potential cumulative impact from underground testing at the Nevada Test Site was not performed for the Final EIS because the principal factors affecting contaminant fate and transport remained essentially unchanged between the TSPA-Viability Assessment and the TSPA-Site Recommendation. DOE considers the estimates of Nevada Test Site groundwater impacts developed using the simplified model conservative and applicable for environmental evaluation. Further, any minor enhancements to these factors incorporated into the TSPA-Site Recommendation would have yielded results for an updated cumulative analysis well within the uncertainty reported for the analysis based on the TSPA-Viability Assessment. Therefore, DOE developed a simplified analysis that uses the TSPA-Viability Assessment (DIRS 101779-DOE 1998, all) repository infiltration and groundwater fate and transport models to scale groundwater impacts that could result from the underground test inventory. The analysis made the following assumptions for this calculation:

- The total 130-million-curie radionuclide inventory from underground testing at the Nevada Test Site would be available for transport. Tritium constitutes about 90 percent of the total underground testing inventory (DIRS 157116-Bowen et al. 2001, Table V, p. 21). However, the short half-life of tritium (about 12.5 years) would mean that radioactive decay would deplete the tritium inventory to insignificant levels in about 200 years, long before any Yucca Mountain releases would occur. Since potential impacts from tritium migration from the Test Site would not overlap repository impacts temporally, they would not be cumulative. Therefore, DOE did not consider them in this analysis.

- The radionuclide inventory available for transport at the repository would be the estimated curie content of the source material that would become wet in the 10,000-year analysis period. The analysis determined this amount by estimating the quantity of source material in the waste packages and cladding that are predicted to fail (*juvenile* and new *failures*) during the analysis period. Assuming that DOE would emplace 10,000 waste packages in the repository, the package failure rates developed in the TSPA-Viability Assessment indicate two waste package failures with 100 percent of contained elements exhibiting failed cladding. Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance, including the waste package design, and improve operational safety and efficiency. The result of the design evolution process was the development of the Science and Engineering Report flexible design (DIRS 153849-DOE 2001, all). In addition, DOE has continued technical development of the Total System Performance Assessment since publication of the Draft EIS, including further site characterization, improvements to the engineered system design, system performance assessment calculations, and quality assurance and validation of results. These efforts have resulted in an updated performance assessment referred to as the Total System Performance Assessment-Site Recommendation [TSPA-Site Recommendation (DIRS 153246-CRWMS M&O 2000)]. The results of this analysis for long-term impacts from the Yucca Mountain Repository are reported in Chapter 5 of this Final EIS. The TSPA-Site Recommendation evaluated the long-term performance of the updated Science and Engineering Report flexible design and included the best available information related to contaminant fate and transport. The results for the groundwater impacts from the repository in this analysis are substantially lower than reported in the Draft EIS. However, an update of this simplified scaling analysis used to estimate the potential cumulative impact from underground testing at the Nevada Test Site was not performed for the Final EIS because the principal factors affecting contaminant fate and transport remained essentially unchanged between the TSPA-Viability Assessment and the TSPA-Site Recommendation. DOE considers the estimates of Nevada Test Site groundwater impacts developed using the simplified model conservative and applicable for environmental evaluation. Further, any minor enhancements to these factors incorporated into the TSPA-Site Recommendation would have yielded results for an updated cumulative analysis well within the uncertainty reported for the analysis based on the TSPA-Viability Assessment.

- The estimated total inventory for all underground tests at the Nevada Test Site was 130 million curies as of September 23, 1992 (DIRS 157116-Bowen et al. 2001, Table V, p. 21). As discussed above, the contribution to the total inventory from subcritical experiments is very small and is adequately accounted for by analyzing the inventory from historical testing (DIRS 156758-Crowe 2001, all). The Department only evaluated the radionuclides of interest (that is, those that result in 99 percent of

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the impact; technetium-99, iodine-129, and carbon-14) in this inventory (see Section 5.4.1 of the Draft EIS for details.)

- The total underground testing inventory available for transport would migrate through the same locations as those considered in this EIS for dose calculations for releases from the repository. This is very conservative because much of the water migrating from the underground test locations would discharge to locations other than those for releases from the proposed repository. Such locations include Oasis Valley, Ash Meadows, or the Amargosa Desert.

- The radionuclide-specific distribution coefficients, k_d, are assumed to be equal for source materials at the repository and the Nevada Test Site. This assumption recognizes that most of the nonvolatile radionuclide inventory at the Test Site is captured within the glass-like material resulting from the intense heat generated by past underground tests. The analysis assumed that the leachability of this material is not remarkably different than that of ceramic spent nuclear fuel pellets. Concentrations of the contaminants (curies per milliliter) in leachates are directly proportional to the source material (curies per gram) and the radionuclide-specific distribution coefficients.

- All contaminants originating on the Nevada Test Site would flow to the same discharge points as contaminants from Yucca Mountain, as modeled by the TSPA-Viability Assessment, and the peak groundwater concentrations of contaminants from the Test Site would coincide (in time and space) with the peak groundwater concentrations from repository contaminants.

- Concentrations of radionuclides in the groundwater would be diluted by total infiltration through the repository footprint and groundwater recharge for the repository and the Nevada Test Site, respectively.

The absolute potential cumulative Nevada Test Site groundwater impact can be estimated by comparison with the 10,000-year impacts presented in Table 5-4 of the Draft EIS. Based on these tables, the estimated cumulative Test Site impacts for the Proposed Action for the maximally exposed individual would be about 0.007 millirem per year at 20 kilometers. The dose to the RMEI at 18 kilometers, as described in Chapter 5, would be slightly higher. Therefore, the estimated total potential cumulative impact (Yucca Mountain impact plus Nevada Test Site impact) would be essentially (because of the small contribution from the proposed repository) 0.007 millirem per year to the RMEI.

Because of the large uncertainties in the current level of understanding of the hydrogeologic system, DOE has not attempted to model the actual groundwater transport of the Nevada Test Site with this simplified model. However, by assuming that the radionuclide contaminants in the groundwater at the Test Site would be transported in an identical manner to those from the repository and that peak concentrations would occur at precisely the same time, the Department believes that the resulting estimates of cumulative impacts from underground testing activities represent a reasonable upper bound of the actual cumulative impacts.

Uncertainties associated with Nevada Test Site groundwater impacts:

- *Source material concentration* – The concentration of contaminants within the source material is the parameter with the most sensitivity to outcome but also the parameter that the least is known about at the Nevada Test Site. However, the actual Test Site concentrations could be higher than those estimated for this analysis and still have little effect on the outcome. This is because, as the density of the Test Site inventory increases (that is, the radionuclide inventory is assumed to occupy a smaller volume), the quantity of infiltration "seen" by the contaminant would decrease because of the reduced footprint of the source term. Since both of these terms (radionuclide density and water infiltration per unit area) are directly proportional to the calculated groundwater concentration, they would tend to offset one another. However, for conservatism, the assumption was made that all of the Test Site source term for radionuclides of interest was concentrated only in the affected soil at Yucca Flat. This assumption could have resulted in an overestimate of the Test Site concentration and potential impacts by as much as two.

- *Travel distances and times* – The conservative assumption was made that the contaminants from Yucca Mountain and the Nevada Test Site would travel along the same pathways (those assumed for Yucca Mountain in the TSPA-Viability Assessment) and at the same time to maximize potential impacts. If more realistic modeling had been performed, the peak contaminate concentrations from Yucca Mountain and the Test Site probably would not coincide and the Test Site contribution to the cumulative impacts would therefore be smaller than those estimated.

- *Solute partition coefficients* – These coefficients as described in the literature are known to vary by orders of magnitude depending on soil and source zone material types. Because the precise nature of the soils at the Nevada Test Site was not considered in the simplified analysis, the actual result could be different. However, these values are not readily available and are impossible to estimate accurately with currently available data.

- *Contaminant mobilization* – To simplify the analysis, the assumption was made that the waste isolated in engineered barrier systems for the Yucca Mountain Repository and the waste dispersed in glass-like material from underground nuclear blasts at the Nevada Test Site will have the same release characteristics. The actual mechanisms for waste mobilization for Test Site underground testing contamination are largely unknown. The actual differences in the mobilization of the contaminants could result in changes (larger or smaller) in the impact estimates, however, due to the relative size of the calculated impacts, coupled with the other conservatisms assumed in this simplified analysis, they are not likely to influence the conclusion.

- *Groundwater flow direction and discharge points* – If realistic modeling was performed, and adequate characterization data to support that modeling was available, then it is extremely unlikely that the modeling would show that all contaminants resulting from underground testing across the Nevada Test Site would migrate to only one discharge point and that point would be the same point of discharge as the releases from the Yucca Mountain Repository. More detailed information on actual groundwater flow would likely serve to reduce the estimated impact of the Test Site inventory.

8.3.2.1.2 *Greater Confinement Disposal*

Waste disposed of at the Nevada Test Site under Greater Confinement Disposal constitutes a radiological source term that is less than 10 percent of the repository radionuclide source term immediately available for groundwater transport when the first waste packages at the Yucca Mountain Repository are assumed to have initially degraded (that is, 2 percent of the total repository radionuclide source term). The waste disposed of by Greater Confinement Disposal was placed in boreholes that are approximately 37 meters (120 feet) deep; the waste itself is no closer than approximately 21 meters (70 feet) to the surface. DOE has reviewed analyses related to the Nevada Test Site and has concluded that there is no credible pathway for long-term releases of materials by resuspension of nonvolatile radionuclides because the material is sufficiently far below the surface. In addition, evapotranspiration exceeds precipitation in this region, which, coupled with the fact that the boreholes are sufficiently above the water table (more than 125 meters), indicates that there is no credible release scenario for Greater Confinement Disposal material to enter the groundwater. Therefore, DOE expects no cumulative impacts from Greater Confinement Disposal activities.

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8.3.2.1.3 *Future Nevada Test Site Low-Level Waste Disposal*

The Nevada Test Site is a disposal site for low-level radioactive waste generated by DOE-approved generators. Managed radioactive waste disposal operations began in the early 1960s, and DOE has disposed of low-level, transuranic, mixed, and classified low-level wastes in selected pits, trenches, landfills, and boreholes on the Nevada Test Site. Environmental impacts from the disposal of low-level waste at the Nevada Test Site are discussed in the Nevada Test Site Final EIS (DIRS 101811-DOE 1996, pp. 2-15 to 2-17). The current source term of low-level and mixed wastes in shallow land disposal on the Nevada Test Site does not constitute a substantial inventory in relation to the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). However, shallow burial of low-level radioactive waste continues to be an important waste disposal activity at the Nevada Test Site. Therefore, this section evaluates reasonably foreseeable future activities in this category as a potential cumulative impact.

Waste disposal activities on the Nevada Test Site occur at two specific locations. They are the Area 3 and Area 5 Radioactive Waste Management Sites. The Area 3 Radioactive Waste Management Site is on Yucca Flat and covers an area of approximately 0.2 square kilometer (50 acres). DOE uses conventional landfill techniques to dispose of contaminated debris from the Nevada Test Site Atmospheric Testing Debris Disposal Program and packaged bulk low-level waste from other DOE sites in subsidence craters from underground nuclear tests. The estimated total remaining capacity for low-level waste in the Area 3 site is 1.8 million cubic meters (64 million cubic feet) (DIRS 103224-DOE 1998, Section A.5.2) .

DOE has used the Area 5 Radioactive Waste Management Site since 1961 to dispose of low-level waste and classified low-level waste from Nevada Test Site operations. In 1978, the Test Site began accepting low-level waste generated by other DOE sites. The total area of the Area 5 site is 3 square kilometers (740 acres). The developed portion occupies 0.37 square kilometer (92 acres) in the southeast corner and contains 17 landfill cells (pits and trenches), 13 Greater Confinement Disposal boreholes, and a transuranic waste storage pad. DOE is seeking a Resource Conservation and Recovery Act permit for Pit 3 as a mixed-waste disposal unit. In the future, if the mixed-waste volume warranted it, the Department might consider obtaining a new unit and, hence, a new permitted facility. However, current projected waste volumes do not indicate the need for an additional mixed-waste disposal unit at this time. The estimated total remaining capacity for low-level waste in the Area 5 Radioactive Waste Management Site is 1.2 million cubic meters (42 million cubic feet) (DIRS 103224-DOE 1998, Section A.5.3).

As discussed in Section 8.2.12.1, DOE projects a need for 1.1 million cubic meters of capacity for low-level waste disposal at the Nevada Test Site through 2070 (DIRS 155856-DOE 2000, Table 4-1).

The Final Waste Management Programmatic EIS (DIRS 101816-DOE 1997, Summary) reported volumes of radioactive waste DOE may dispose of at the Nevada Test Site for “current plus 20 years” of waste disposal. The current inventory plus 20 years of additional disposal inventory would total 3,000 cubic meters (106,000 cubic feet) of low-level mixed waste, 1,700 cubic meters (60,000 cubic feet) of low-level waste, and 610 cubic meters (21,500 cubic feet) of transuranic waste (DIRS 101816-DOE 1997, Summary, p. 102). The Nevada Test Site Final EIS (DIRS 101811-DOE 1996, Table 4-1, p. 4-6) estimates the total current inventory already in shallow disposal at the Nevada Test Site to be 500,000 curies at the time of disposal (uncorrected for decay to the present time).

According to the Final Waste Management Programmatic EIS, the only expected groundwater impacts from low-level mixed, low-level radioactive, and transuranic waste disposal at the Nevada Test Site in excess of regulatory limits are for the hazardous chemicals 1,2-dichloroethane, methylene chloride, and benzene, and those only under Regionalized Alternative 3 and the Preferred Alternative in that EIS (DIRS 101816-DOE 1997, p. 11-61). None of these hazardous chemicals would be in the Yucca Mountain

Repository inventory, so there would be no potential cumulative impacts from those chemicals from the Proposed Action or Inventory Module 1 or 2.

DOE has estimated potential long-term impacts from radioactive material disposed of at the Nevada Test Site. DOE based its calculations of long-term atmospheric releases for the Nevada Test Site on estimates of the inventory at the Test Site that could be accessible by residents around the area. For this calculation, the Department considered three potential sources of radionuclide releases:

- The Area 3 radioactive waste disposal area
- The Area 5 radioactive waste disposal area
- Soil sites around the Nevada Test Site that are contaminated at or near the surface from nuclear weapons testing

Because this material is not near the water table and because evapotranspiration exceeds precipitation in this area, there is no credible release scenario for this material to enter the groundwater. DOE postulated that, over time, weathering at the site could resuspend contaminants in the air and transport them from the contaminated areas to offsite residents. Therefore, DOE performed calculations using current meteorological information for the Nevada Test Site and site-specific resuspension factors to estimate the amount of material that could be released off the site. To ensure conservatism in the estimate, DOE assumed that the three sources listed above were in the same location (even though in reality they are separated by large distances) and that a future resident could be as near as 100 meters (330 feet) from the site. Analyses based on these assumptions are likely to overestimate the true impacts to a future resident because they result in a calculated total emission and radiation dose that is probably higher than if a resident were within 100 meters of a single site.

Based on these conservative assumptions, DOE calculated that the total radiation dose from the three sources could be approximately 7 millirem for each year of exposure during the first 10,000 years, and DOE does not expect that the dose would increase beyond that value for as long as 1,000,000 years. If a resident received this dose as long as 70 years, that person's lifetime dose could be as high as 490 millirem, which could result in an increased risk of fatal cancer of 0.0002.

8.3.2.2 Past Actions and Present Actions at the Beatty Low-Level Radioactive Waste Disposal and Hazardous Waste Treatment Storage and Disposal Facilities

A low-level radioactive waste disposal facility, formerly operated by U.S. Ecology, a subsidiary of American Ecology, is 16 kilometers (10 miles) southeast of Beatty, Nevada, and 180 kilometers (110 miles) northwest of Las Vegas. This site is about 15 kilometers (9.3 miles) west of the proposed Yucca Mountain Repository (see Figure 8-2). The disposal facility, which opened in 1962, covers roughly 0.14 square kilometer (35 acres) of unlined trenches. Acceptance of low-level radioactive waste ended December 31, 1992 (DIRS 101815-DOE 1997, Chapter 4, Table 4-17). The Nevada State Health Division formally accepted permanent custody of the low-level radioactive commercial waste disposal in a letter to American Ecology dated December 30, 1997 (DIRS 148088-AEC 1998, all). An adjacent U.S. Ecology facility remains open for hazardous waste disposal.

From 1962 through 1992, the inventory shipped to the Beatty low-level radioactive waste facility totaled 137,000 cubic meters (4.8 million cubic feet) in volume (DIRS 101815-DOE 1997, Chapter 4, Table 4-17) with radioactivity of about 640,000 curies (DIRS 101815-DOE 1997, Chapter 4, Table 4-18). The radioactivity in this sum was measured by year of shipment (that is, it is not corrected for decay since that time).

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The Manifest Information Management System (DIRS 148160-MIMS 1992, all) calculated the total radionuclide inventory the Beatty facility received from 1986 through 1992, which represents 29 percent of the total undecayed inventory at that facility. Even if multiplied by a factor of 3 to 4 to compensate for the period (1962 to 1985) for which the Manifest Information Management System did not provide information, the source term represents a small percentage of the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). Therefore, cumulative long-term impacts from the Beatty Low-Level Radioactive Waste Disposal Facility with the repository would be very small.

The U.S. Ecology Hazardous Waste Treatment, Storage and Disposal Facility is a Resource Conservation and Recovery Act-permitted facility, with engineered barriers and systems and administrative controls that minimize the potential for offsite migration of hazardous constituents.

8.4 Cumulative Transportation Impacts

This section discusses the results of the cumulative impact analysis of transportation. Paralleling the transportation analyses of the Proposed Action in Chapter 6, potential national transportation cumulative impacts from Inventory Module 1 or 2, and past, present, and reasonably foreseeable future actions, are presented in Section 8.4.1. Potential cumulative impacts with construction and operation of the Nevada transportation implementing rail and heavy-haul truck alternatives are included in Section 8.4.2.

The shipment of Inventory Module 1 or 2 to the repository would use the same transportation routes, but would take more shipments and an additional 14 years compared to the Proposed Action. Table 8-2 lists the estimated number of shipments for Modules 1 and 2. Impacts from Module 1 or 2 would be similar because the shipping rate would be the same for spent nuclear fuel and high-level radioactive waste and only about 3 percent more shipments would be made over the 38-year period under Module 2 to transport Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. Because the difference in impacts between Inventory Modules 1 and 2 would be small, the following discussions present the impacts from both modules as being the same.

8.4.1 NATIONAL TRANSPORTATION

This section describes cumulative impacts from national transportation. Section 8.4.1.1 presents potential cumulative impacts from shipping Inventory Module 1 or 2 from commercial nuclear generating sites and DOE facilities to the proposed Yucca Mountain Repository (Section 8.4.1.1). Section 8.4.1.2 presents potential cumulative national transportation impacts for the Proposed Action and Module 1 or 2 when combined with past, present, and reasonably foreseeable future shipments of radioactive material.

8.4.1.1 Inventory Module 1 or 2 Impacts

This section describes the potential cumulative impacts of loading operations at generating sites and incident-free radiological impacts, vehicle emission impacts, and accident impacts associated with transportation activities for Inventory Module 1 or 2. Cumulative impact results are provided for the mostly legal-weight truck and mostly rail scenarios which are described in Chapter 6. The section also describes potential cumulative impacts from transportation of other materials, personnel, and repository-generated waste for Modules 1 or 2. Appendix J contains additional detailed analysis results.

Loading operations would be extended for an additional 14 years to load the greater quantities of spent nuclear fuel and high-level radioactive waste under Inventory Module 1 or 2. The impacts of routine loading operations described for the Proposed Action in Chapter 6, Section 6.2.2, would increase for Module 1 or 2 due to the additional inventory. Therefore, the increase in dose to the public would be about 42 person-rem based on 0.001 person-rem per metric ton of heavy metal and 42,000 additional MTHM (46,000 tons) (DIRS 104731-DOE 1986, Volume 2, p. E.6) for Modules 1 and 2. This dose could result in an additional 0.02 cancer fatality in the exposed population. Table 8-54 lists estimated radiological and industrial hazard impacts to involved workers for the routine loading operations under Module 1 or 2. The Proposed Action impacts are listed for comparison.

Table 8-54. Radiological and industrial hazard impacts to involved workers from loading operations.[a,b]

Impact	Proposed Action[b]		Inventory Module 1 or 2	
	Mostly legal-weight truck scenario	Mostly rail scenario	Mostly legal-weight truck scenario	Mostly rail scenario
Radiological				
Maximally exposed individual				
Dose (rem)[c]	12	12	12	12
Probability of latent cancer fatalities	0.005	0.005	0.005	0.005
Involved worker population				
Dose (person-rem)	15,000	4,200	32,000	8,400
Number of latent cancer fatalities	6.0	1.7	13	3.4
Industrial hazards				
Total recordable cases[d]	380	130	770	260
Lost workday cases[e]	200	70	400	130
Fatalities[f]	0.88	0.3	1.8	0.6

a. Includes all involved workers at all facilities and does not vary by operating mode.
b. Source: Chapter 6, Section 6.2.
c. Assumes 500 millirem per year to radiation workers. The average individual exposure was assumed to be 24 years for both the Proposed Action and Inventory Module 1 or 2 since 24 years is a conservatively long time to assume an individual would be involved in loading operations.
d. Total recordable cases based on a loss incidence rate of 0.084.
e. Lost workday cases based on a loss incidence rate of 0.046.
f. Fatalities based on a loss incidence rate of 0.000218.

Because noninvolved workers would not have tasks that involved radioactive exposure, there would be no or very small radiological impacts to noninvolved workers. For the reasons identified in Chapter 6, Section 6.2.2.2, industrial hazard impacts to noninvolved workers would be about 25 percent of the impacts to the individual worker shown in Table 8-54.

The impacts of loading accident scenarios under Inventory Module 1 or 2 would be the same as those described for the Proposed Action in Chapter 6, Section 6.2.4.1. The same type of single accident event and its impacts are applicable to shipments under the Proposed Action or Module 1 or 2. As summarized in Chapter 6, Section 6.2.4.1, the analysis results indicate that there would be no or very small potential radiological consequences from loading accident scenarios involving spent nuclear fuel or high-level radioactive waste. These consequences would bound the consequences from similar accidents involving Greater-Than-Class-C or Special-Performance-Assessment-Required waste because of the lower available radionuclide inventory (see Appendix A).

Table 8-55 lists radiological impacts to involved workers and the public and vehicle emission impacts from incident-free transportation for the mostly legal-weight truck and mostly rail scenarios. The analysis of impacts for the mostly legal-weight truck scenario assumed that shipments would use commercial motor carriers for highway transportation and general freight commercial services for rail transportation for the naval spent fuel shipments that cannot be transported by legal-weight trucks. The mostly rail analysis accounts for legal-weight truck shipments that would occur for the commercial nuclear generator sites that do not currently have the capacity to handle or load rail casks. In addition, for the mostly rail analysis, DOE assumed that it would use either a branch rail line or heavy-haul trucks in conjunction with an intermodal transfer station in Nevada to transport the large rail casks to and from the

Table 8-55. Radiological and vehicle emission impacts from incident-free national transportation.

Category	Proposed Action[a,b]		Inventory Module 1 or 2[c]	
	Mostly legal-weight truck scenario[d]	Mostly rail scenario[e]	Mostly legal-weight truck scenario[d]	Mostly rail scenario[e]
Involved worker				
Collective dose (person-rem)	14,000	3,700 - 4,600	28,000	7,100 - 8,800
Estimated number of latent cancer fatalities	5.6	1.5 - 1.9	11.2	2.8 - 3.5
Public				
Collective dose (person-rem)	5,000	1,200 - 1,600	9,700	2,200 - 3,100
Estimated number of latent cancer fatalities	2.5	0.6 - 0.82	5.0	1.1 - 1.6
Estimated vehicle emission-related fatalities	0.95	0.5 - 0.8	1.9	0.9 - 1.4

a. Source: Chapter 6, Section 6.2.3.
b. Impacts are totals for shipments over 24 years.
c. Impacts are totals for shipments over 38 years.
d. Includes rail shipments of naval spent nuclear fuel to Nevada, and intermodal transfer station and heavy-haul truck operations for this fuel in Nevada.
e. Includes legal-weight truck shipments from commercial nuclear generator sites that do not have the capacity to handle or load rail casks, and the rail and heavy-haul truck implementing alternatives for Nevada described in Chapter 6.

repository. The range provided in the table for the mostly rail scenario addresses the different possible rail and heavy-haul truck implementing alternatives described in Chapter 6. The lower end of the range reflects use of a branch rail line in Nevada and the upper end of the range reflects use of heavy-haul trucks in Nevada. The involved worker impacts in Table 8-55 include estimated radiological exposures of truck and rail transportation crews and security escorts for legal-weight truck and rail shipments; the public doses account for the public along the route, the public sharing the route, and the public during stops. The Inventory Module 1 or 2 impacts would exceed those of the Proposed Action due to the additional number of shipments.

DOE does not expect radiological impacts for maximally exposed individuals to change from the Proposed Action due to the conservative assumptions used in the analysis of the Proposed Action (see Chapter 6, Section 6.2.3). The assumptions for estimating radiological dose include the use of the maximum allowed dose rate and conservative estimates of exposure distance and time. For example, the U.S. Department of Transportation maximum allowable dose rate of 10 millirem per hour at a distance of 2 meters (6.6 feet) [40 CFR 173.44(b)] was used for estimating exposure to individuals. In addition, the conservative assumptions for exposure distance and time for workers (that is, crew members, inspectors, railyard crew member) and the public (that is, resident along route, person in a traffic jam, person at a service station, resident near a rail stop) for the Proposed Action are unlikely to be exceeded for Inventory Module 1 or 2 (see Chapter 6, Section 6.2.3).

Table 8-56 lists the radiological accident risk and traffic fatalities for transportation by mostly legal-weight truck and mostly rail for Inventory Module 1 or 2. The radiological accident risk measures the total impact of transportation accidents over the entire shipping campaign (24 years for the Proposed Action and 38 years for Module 1 or 2). The consequences from a maximum reasonably foreseeable accident scenario would be identical to those discussed for the Proposed Action (see Chapter 6, Sections 6.2.4.2.1 and 6.2.4.2.2) because the parameters and conditions for the hypothetical accident event involving spent nuclear fuel or high-level radioactive waste would be the same for a shipment under the Proposed Action or Module 1 or 2. In addition, the hypothetical accident would be bounding for accident scenarios involving Greater-Than-Class-C and Special-Performance-Assessment-Required wastes.

As summarized in Chapter 6, Section 6.1.3, and further described in Appendix J, in addition to the transportation of spent nuclear fuel and high-level radioactive waste to the repository, other materials

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Table 8-56. Accident risk for mostly legal-weight truck and mostly rail scenarios.

Category	Proposed Action[a]		Inventory Module 1 or 2	
	Mostly legal-weight truck scenario	Mostly rail scenario	Mostly legal-weight truck scenario	Mostly rail scenario
Radiological accident risk				
Collective dose risk (person-rem)	0.46	0.8 - 1.0	0.87	1.3 - 1.6
Estimated number of latent cancer fatalities	0.00023	0.00041 - 0.00050	0.00043	0.00066 - 0.00080
Traffic accident fatalities	4.9	2.3 - 3.1	8.7	4.2 - 5.9

a. Source: Chapter 6, Section 6.2.4.2.

would require transportation to and from the proposed repository. These materials would include construction materials, consumables, repository components (disposal containers, drip shields, etc.), office and laboratory supplies, mail, and laboratory samples. Required transportation would also include personnel commuting to the Yucca Mountain site and the shipment of repository-generated wastes offsite for treatment, storage, or disposal.

The implementation of Inventory Module 1 or 2 would increase this transportation as a result of the additional required subsurface development and the longer time required for repository development, emplacement, and closure. However, even with the increased transportation of other material, personnel, and repository-generated wastes for Module 1 or 2, DOE would expect these transportation impacts to be small contributors to the total transportation impacts on a local, state, and national level with no large cumulative impacts based on the analysis of the Proposed Action in Section 6.1.3. The annual air quality impacts for Inventory Module 1 or 2 would be the same as those conservatively estimated in Section 6.1.3 and, therefore, no cumulative air quality impacts would be expected in the Las Vegas airshed, which is in nonattainment for carbon monoxide. Table 8-57 summarizes fatalities from transporting other materials, personnel, and repository-generated waste. The estimated fatalities assume truck shipments in Nevada which would have higher potential impacts than shipments by rail. The Proposed Action impacts are listed in the table for comparison.

Table 8-57. Impacts from transportation of materials, consumables, personnel, and waste.[a,b]

Category	Proposed Action		Inventory Module 1 or 2	
	Kilometers traveled[c]	Fatalities	Kilometers traveled (Module 1/Module 2)	Fatalities (Module l/Module 2)
Materials (including repository components)	130,000,000 - 270,000,000	4.1 - 7.8	170,000,000 - 310,000,000	5.6 - 9.8
Personnel	480,000,000 - 800,000,000	5.4 - 9.2	640,000,000 - 930,000,000	7.3 - 11
Repository-generated waste				
Hazardous	57,000 - 71,000	0.001 - 0.002	110,000 - 170,000	0.002 - 0.003
Low-level radioactive	230,000 - 320,000	0.004 - 0.006	430,000 - 1,000,000	0.008 - 0.02
Nonhazardous solid	5,600,000 - 10,400,000	0.1 - 0.2	7,000,000 - 9,500,000	0.13 - 0.18
Totals	***610,000,000 - 1,100,000,000***	***9.6 - 17***	***820,000,000 - 1,300,000,000***	***13 - 20***

a. Totals might differ from sums of values due to rounding.
b. Source: Appendix J, Section J.3.6.
c. To convert kilometers to miles, multiply by 0.62137.

8.4.1.2 Cumulative Impacts from the Proposed Action, Inventory Module 1 or 2, and Other Federal, Non-Federal, and Private Actions

The overall assessment of cumulative national transportation impacts for past, present, and reasonably foreseeable future actions concentrated on the cumulative impacts of offsite transportation, which would yield potential radiation doses to a greater portion of the general population than onsite transportation and would result in fatalities from traffic accidents. The collective dose to workers and to the general population was used to quantify overall cumulative radiological transportation impacts. This measure was chosen because it could be related directly to latent cancer fatalities using a cancer risk coefficient and because of the difficulty in identifying a maximally exposed individual for shipments throughout the United States from 1943 through 2047. Operations at the Hanford Site and the Oak Ridge Reservation began in 1943, and 2047 is when the EIS analysis assumed that radioactive material shipments to the repository for Inventory Module 1 or 2 would end. The source of this cumulative transportation impacts analysis is the Yucca Mountain EIS Environmental Baseline File on transportation (DIRS 104800-CRWMS M&O 1999, Section 7.0), with the exception of impacts from the Proposed Action and Module 1 or 2, which are from Table 8-55.

The cumulative impacts of the transportation of radioactive material would consist of impacts from:

- Historic DOE shipments of radioactive material associated with the Nevada Test Site, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, the Hanford Site, the Oak Ridge Reservation, and naval spent nuclear fuel and test specimens

- Reasonably foreseeable actions that include the transportation of radioactive material identified in DOE Environmental Policy Act analyses; for example, the Nevada Test Site Environmental Impact Statement (DIRS 101811-DOE 1996, all), the Department of Energy Spent Nuclear Fuel Management Environmental Impact Statement (DIRS 101802-DOE 1995, all; DIRS 101812-DOE 1996, all), and the Final Department of Energy Waste Management Environmental Impact Statement (DIRS 101816-DOE 1997, all) (see Table 8-58). In some cases, transportation impacts included impacts that may have been double counted. For example, the transportation impacts from shipping 40,000 MTHM of spent nuclear fuel to a potential Private Fuel Storage Facility in Tooele County, Utah (DIRS 152001-NRC 2000, all) were included in Table 8-58, but the transportation impacts from the Proposed Action were not decreased to account for this 40,000 MTHM. Table 8-58 also includes reasonably foreseeable projects that include limited transportation of radioactive material (for example, shipment of submarine reactor components from the Puget Sound Naval Shipyard to the Hanford Site for burial, and shipments of uranium billets and low-specific-activity nitric acid from the Hanford Site to the United Kingdom). In addition, for reasonably foreseeable future actions where a preferred alternative was not identified or a Record of Decision has not been issued, the analysis used the alternative estimated to result in the largest transportation impacts. While this is not an exhaustive list of the projects that could include limited transportation of radioactive material, it indicates that the transportation impacts associated with such projects are low in comparison to major projects or general transportation.

- General radioactive materials transportation that is not related to a particular action; for example, shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities

- Shipments of spent nuclear fuel, high-level radioactive waste, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste under the Proposed Action or Inventory Module 1 or 2

Table 8-58 summarizes the worker and general population doses from the transport of radioactive material. The estimated total cumulative transportation-related collective worker doses from the mostly legal-weight truck shipments (past, present, and reasonably foreseeable actions) with the Proposed Action would be about 360,000 person-rem (140 latent cancer fatalities), and with Inventory Module 1 or 2 about 410,000 person-rem (160 latent cancer fatalities). The estimated total general population doses for the mostly legal-weight truck shipments would be about 320,000 person-rem (160 latent cancer fatalities) with the Proposed Action, and about 350,000 person-rem (180 latent cancer fatalities) with Module 1 or 2. Most of the dose for workers and the general population would be due to general transportation of radioactive material. The estimated total cumulative number (workers plus population) of latent cancer fatalities with the Proposed Action would be about 300, and about 340 with Module 1 or 2. To place

Table 8-58. Cumulative transportation-related radiological doses, latent cancer fatalities, and traffic fatalities.[a]

Category	Worker dose (person-rem)	General population dose (person-rem)	Traffic fatalities
Historical DOE shipments (DIRS 101811-DOE 1996, all)	330	230	NL[b]
Reasonably foreseeable actions			
Private Fuel Storage Facility (DIRS 152001-NRC 2000, all)	29	190	0.78
Sodium-Bonded Spent Nuclear Fuel (DIRS 157167-DOE 2000, all)	0.0044	0.032	0.0001
Idaho High-Level Waste and Facilities (DIRS 155100-DOE 1999, all)	530	2,900	0.1
Surplus Plutonium Disposition (DIRS 118979-DOE 1999, all)	60	67	0.053
Sandia National Laboratories Site-Wide EIS (DIRS 157155-DOE 1999, all)	94	590	1.3
Depleted Uranium Hexafluoride (DIRS 152493-DOE 1999, all)	--[c]	750	4
Tritium Production in a Commercial Light Water Reactor (DIRS 157166-DOE 1999, all)	16	80	0.06
Parallex Project (DIRS 157153-DOE 1999, all)	0.00001	0.00007	0.00005
Los Alamos National Laboratory Site-Wide EIS (DIRS 157154-DOE 1999, all)	580	310	8
Plutonium Residues at Rocky Flats (DIRS 155932-DOE 1998, all)	2.1	1.3	0.0078
Import of Russian Plutonium-238 (DIRS 157156-DOE 1993, all)	1.8	4.4	0.0036
Nevada Test Site expanded use (DIRS 101811-DOE 1996, all)	--	150[d]	8
Spent nuclear fuel management (DIRS 101802-DOE 1995, all; DIRS 101812-DOE 1996, all)	360	810	0.77
Waste Management PEIS (DIRS 101816-DOE 1997, all)[e]	16,000	20,000	36
Waste Isolation Pilot Plant (DIRS 101814-DOE 1997, all)	790	5,900	5
Molybdenum-99 production (DIRS 101813-DOE 1996, all)	240	520	0.1
Tritium supply and recycling (DIRS 103208-DOE 1995, all)	--	--	0.029
Surplus HEU disposition (DIRS 103216-DOE 1996, all)	400	520	1.1
Storage and Disposition of Fissile Materials (DIRS 103215-DOE 1996, all)	--	2,400[d]	5.5
Stockpile Stewardship (DIRS 103217-DOE 1996, all)	--	38[d]	0.064
Pantex (DIRS 103218-DOE 1996, all)	250[f]	490[d]	0.006
West Valley (DIRS 101729-DOE 1996, all)	1,400	12,000	3.6
S3G and D1G prototype reactor plant disposal (DIRS 103221-DOE 1997, all)	2.9	2.2	0.010
S1C prototype reactor plant disposal (DIRS 103219-DOE 1996, all)	6.7	1.9	0.0037
Container system for Naval spent nuclear fuel (DIRS 101941-USN 1996, all)	11	15	0.045
Cruiser and submarine reactor plant disposal (DIRS 103479-USN 1996, all)	5.8	5.8	0.00095
Submarine reactor compartment disposal (DIRS 103477-USN 1984, all)	--	0.053	NL
Uranium billets (DIRS 103189-DOE 1992, all)	0.50	0.014	0.00056
Nitric acid (DIRS 103212-DOE 1995, all)	0.43	3.1	NL
General radioactive material transportation			
1943 to 2033	310,000	260,000	19
1943 to 2047	330,000	290,000	22
Subtotal of non-repository-related transportation impacts			
1943 to 2033	**330,000**	**310,000**	**94**
1943 to 2047	**350,000**	**340,000**	**97**
Proposed Action			
Mostly legal-weight truck	29,000	5,000	4.5
Mostly rail	7,900 - 8,800	1,200 - 1,600	2.3 - 3.1
Module 1 or 2[g]			
Mostly legal-weight truck	60,000	9,700	8.7
Mostly rail	16,000 - 17,000	2,200 - 3,100	4.2 - 5.9
Total collective dose (total latent cancer fatalities)[h] *and total traffic fatalities*			
Proposed Action			
Mostly legal-weight truck	360,000 (140)	320,000 (160)	98
Mostly rail	340,000 (140)	310,000 (160)	97
Module 1 or 2[g]			
Mostly legal-weight truck	410,000 (160)	350,000 (180)	110
Mostly rail	370,000 (150)	340,000 (170)	100

a. Sources: DIRS 104800-CRWMS M&O (1999, Section 7) except for the Proposed Action and Inventory Module 1 or 2, which are from Table 8-54. All references in this table refer to the original source of information cited in DIRS 104800-CRWMS M&O (1999, Section 7).
b. NL = not listed.
c. -- = reported or included with the general population dose.
d. Includes worker and general population doses.
e. Includes mixed low-level waste and low-level waste; transuranic waste included in DIRS 101814-DOE (1997, Volume 1).
f. Includes all highly enriched uranium shipped to Y-12.
g. The transportation-related radiological collective doses for Inventory Module 1 or 2 include the doses from the Proposed Action (see the definition of Modules 1 and 2 in Section 8.1.2.1).
h. The conversion factors for worker and general population dose to latent cancer fatalities are 0.0004 and 0.0005 latent cancer fatality per person-rem, respectively (DIRS 101856-NCRP 1993, p. 31) occurred in the United States. Therefore, the number of vehicular accident fatalities was used to quantify the cumulative impacts of transportation accidents.

these numbers in perspective, there were 541,532 deaths in the United States during 1998 due to cancer, although the number for any given year understandably fluctuates (DIRS 153066-Murphy 2000, p. 83). This section presents an estimate of latent cancer fatalities slightly greater than 300 over a period of about 100 years (that is, an average of about 3 latent cancer fatalities per year). This value would be indistinguishable from the natural fluctuations in the death rate from cancer.

For transportation accidents involving radioactive material, the dominant risk is due to accidents that are not related to the cargo (traffic or vehicular accidents). Typically, the radiological accident risk (latent cancer fatalities) from transportation accidents is less than 1 percent of the vehicular accident risk (see Table 8-56). In addition, no acute radiological fatalities due to transportation accidents have ever occurred in the United States. Therefore, the number of vehicular accident fatalities was used to quantify the cumulative impacts of transportation accidents.

From 1943 through 2033 an estimated 4 million people would be killed in motor vehicle accidents and 180,000 people would be killed by railroad accidents. From 1943 through 2047, an estimated 4.4 million people would be killed in motor vehicle accidents and 200,000 people would be killed in railroad accidents. Based on the estimated number of traffic fatalities for the reasonably foreseeable actions and for the Proposed Action and Inventory Module 1 or 2 listed in Table 8-58, the transport of radioactive material would contribute about 110 fatalities to these totals.

8.4.2 NEVADA TRANSPORTATION

This section analyzes potential cumulative impacts that Inventory Module 1 or 2 and past, present, and other reasonably foreseeable future Federal, non-Federal, and private actions could have on the construction and operation of a branch rail line or the construction and operation of an intermodal transfer station and associated highway upgrades for heavy-haul trucks in the State of Nevada. The analysis included potential cumulative impacts in the vicinity of the five potential branch rail line corridors, the three potential intermodal transfer station locations, and the five associated potential highway routes for heavy-haul trucks.

With respect to potential cumulative impacts from Inventory Module 1 or 2, there would be no cumulative construction impacts because the need for a new branch rail line or new intermodal transfer station and associated highway upgrades for heavy-haul trucks would not change; that is, whatever DOE would build for the Proposed Action would also serve Module 1 or 2. In addition, because the planned annual shipment rate of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository would be about the same for Module 1 or 2 and the Proposed Action, the only cumulative operations impacts would result because of the extra 14 years of shipping time required for Module 1 or 2. With this basis, the operation and maintenance of a branch rail line or an intermodal transfer station and associated highway route for heavy-haul trucks were analyzed for potential cumulative impacts from Module 1 or 2.

Land-use and ownership impacts identified in Chapter 6 (Section 6.3) would be avoided or otherwise resolved to implement the Proposed Action. However, additional conflicts associated with continued use of the affected land areas could occur due to shipping operations being excluded 14 years beyond that analyzed in the Proposed Action. DOE expects no cumulative impacts from the extended 14 years of operation for Inventory Module 1 or 2 to air quality; hydrology (surface water and groundwater); biological resources and soils; cultural resources; socioeconomics; noise; aesthetics; and utilities, energy, and materials, the impacts of which were assessed on a per shipment, weekly, or annual basis (see Chapter 6, Section 6.3).

Cumulative impacts from Inventory Module 1 or 2 to occupational and public health and safety are included in the occupational and public health and safety impacts of national transportation in

Section 8.4.1. The operation of an intermodal transfer station for more years under Module 1 or 2 would affect waste management impacts. Because of the additional years of operation, more waste of the same types would be generated than for the Proposed Action. However, the small waste quantities generated for Module 1 or 2 would have a minimal impact to the receiving treatment and disposal facilities. Because there would be no large cumulative impacts for any of the resource areas from Module 1 or 2, disproportionately high and adverse cumulative impacts to minority or low-income populations or to Native Americans would be unlikely.

Other than Inventory Module 1 or 2, one other Federal action and several private actions could have the potential for cumulative impacts with the construction and operation of a new branch rail line or intermodal transfer station and associated highway route for heavy-haul trucks.

One private action that could lead to cumulative impacts with the Carlin rail corridor implementing alternative is by Cortez Gold Mine, Inc., which has an existing Pipeline Project mining operation and processing facility (DIRS 103078-BLM 1996, all), a proposed Pipeline Infiltration Project (DIRS 103081-BLM 1999, all), and a possible Pipeline Southeast Expansion Project (DIRS 103078-BLM 1996, p. 5-7) in the Crescent Valley area of Nevada through which the Carlin branch rail line would pass (see Section 8.1.2.3 and Figure 8-5). Because the Carlin corridor would pass through the general area of these projects, there could be cumulative land-use and ownership impacts that would require mitigation.

The analysis for the Carlin rail corridor represents the maximum impact; other rail corridor implementing alternatives would have smaller impacts. Cumulative impacts for the mostly legal-weight truck scenario would also have smaller impacts.

Another private action that could result in cumulative impacts would be shared use of a branch rail line that DOE constructed and operated to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository by others (for example, mine operators, private freight shippers) because of the increased rail traffic. Because predicting the increase in rail traffic is not possible at this time, this analysis cannot estimate the cumulative impacts. There could be some added impacts to all the resource areas beyond those evaluated for the Proposed Action in Chapter 6, but there could also be benefits from the improved economic potential for resource development in interior areas of Nevada as well as greater economic development potential for nearby communities. DOE would have to consider these impacts in any decision it made to allow shared use of the branch rail line.

One Federal action and one private action could lead to cumulative impacts with the construction and operation of the Caliente intermodal transfer station. DOE has specified the Caliente site as one of four possible locations for the construction and operation of an intermodal transfer station for the shipment of low-level radioactive waste to the Nevada Test Site (DIRS 103225-DOE 1998, pp. 2-4 to 2-12). In addition, a commercial venture planned by Apex Bulk Commodities for the Caliente site would construct an intermodal transfer station for the transport of copper concentrate. Figure 8-6 shows a possible layout plan for these intermodal transfer stations at Caliente. Section 8.1 provides more information on the potential DOE and Apex intermodal transfer stations. The following sections describe the potential cumulative impact analysis at the Caliente site from the construction and operation of an intermodal transfer station to support the proposed Yucca Mountain Repository, coupled with an intermodal transfer station for shipment of low-level radioactive waste to the Nevada Test Site and an intermodal transfer station proposed by Apex Bulk Commodities.

8.4.2.1 Land Use and Ownership

Chapter 6, Section 6.1.2.1, discusses reasonably foreseeable actions along the rail corridors and heavy-haul truck routes as they would apply to the Proposed Action. The differences in Module 1 and Module 2 in comparison to the Proposed Action are discussed below.

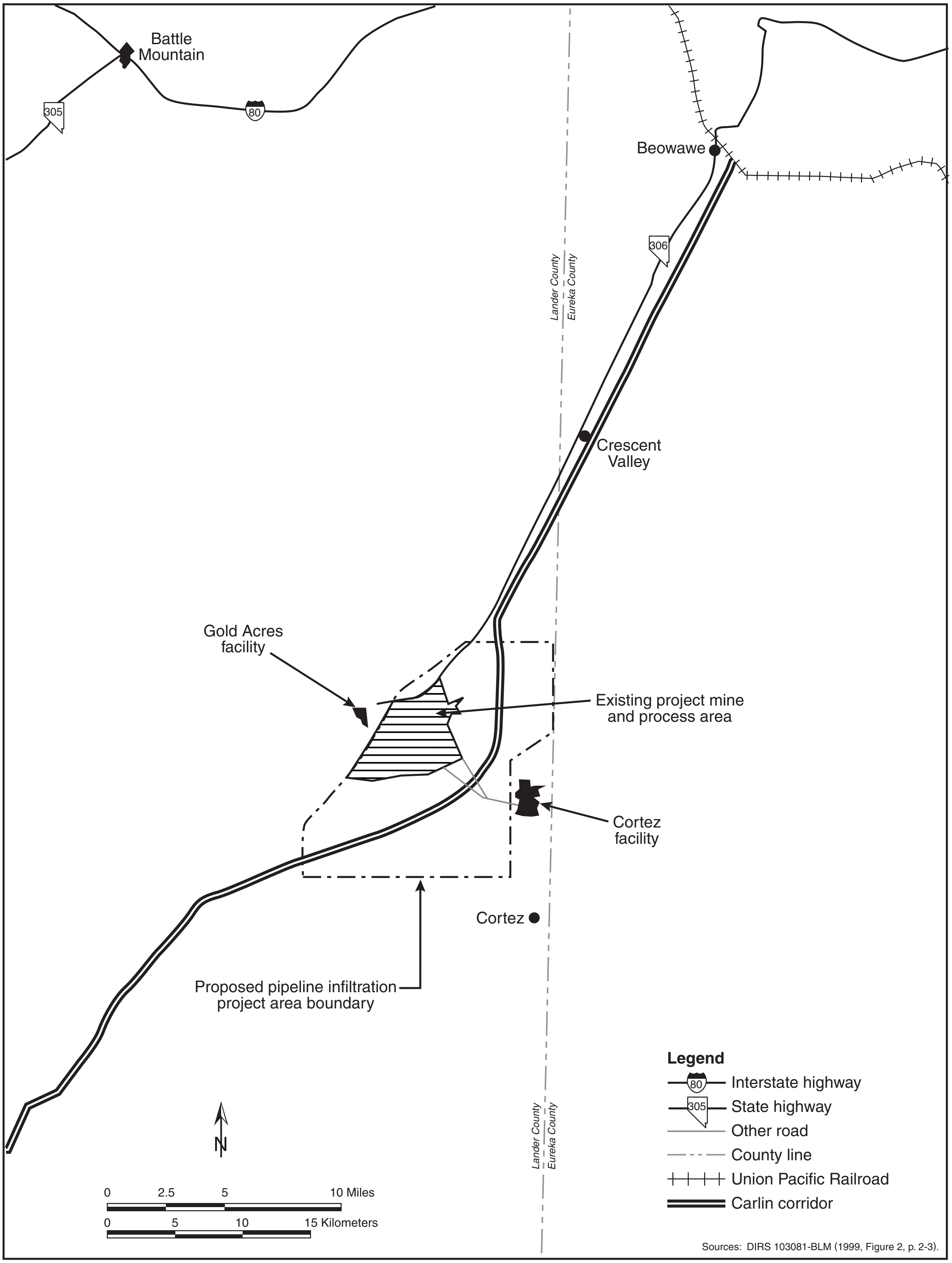

Figure 8-5. Cortez Gold Mine existing pipeline project and proposed pipeline infiltration project.

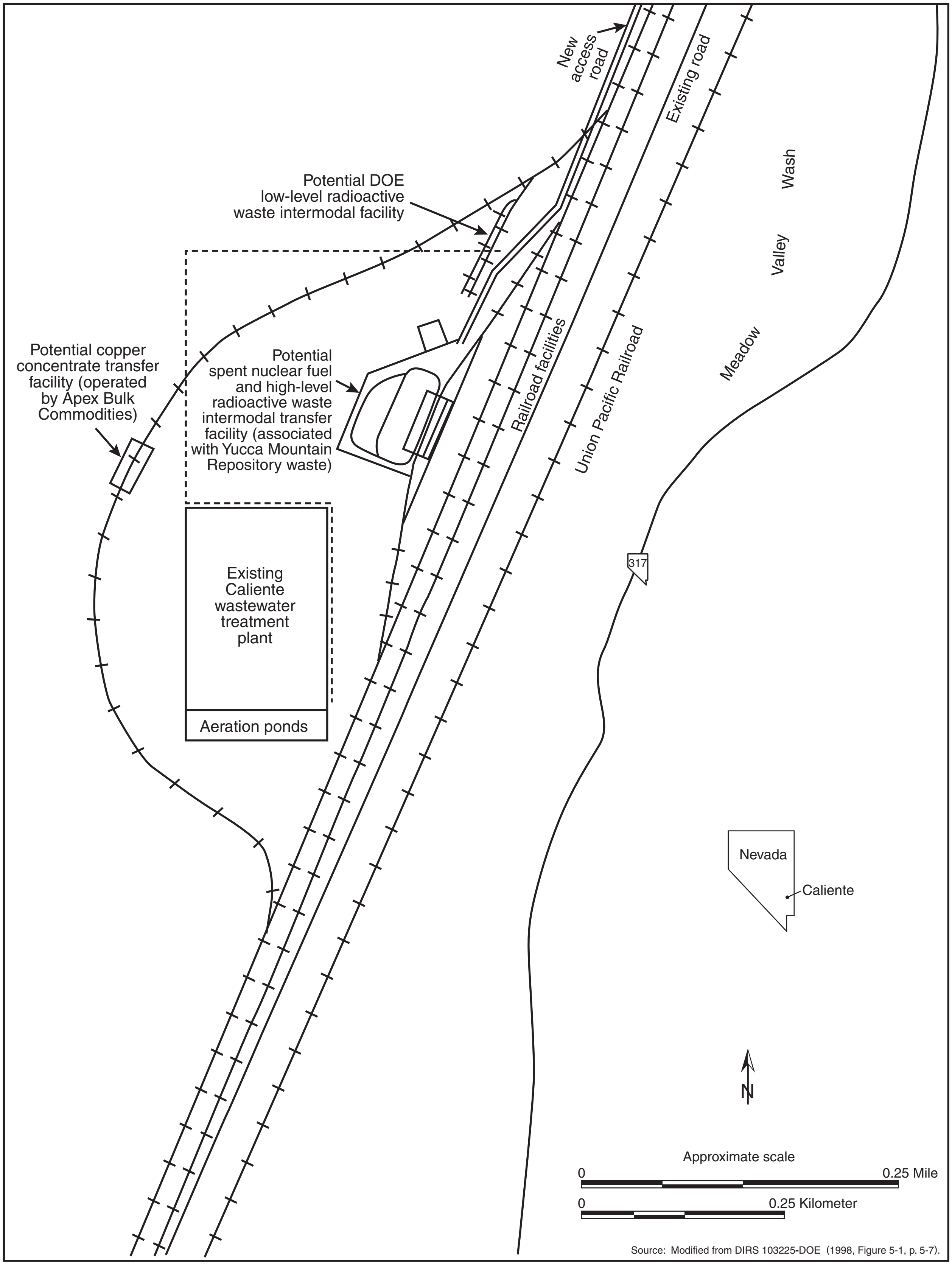

Figure 8-6. Potential locations of intermodal transfer stations at Caliente.

As discussed in Chapter 6, Section 6.3.2.1 there are currently 20 new electric generating plants proposed for the State of Nevada. Of these, 13 are proposed for Clark County in southern Nevada. Currently, plant details are not readily available for a detailed evaluation. However, should these plants be constructed, the rights-of-way necessary for transmission lines and/or natural gas supply lines will most likely be constructed on Bureau of Land Management lands. This would increase the amount of public lands in Nevada that would not be available to other users. Actual impacts associated with the rights-of-way, especially to the candidate rail corridors, would be similar to existing rights-of-way discussed in Section 6.3.2.1.

Section 6.3 of Chapter 6 and Section J.3.1.1 of Appendix J also discuss potential land use and ownership conflicts along candidate rail corridors that could result from the Proposed Action. These include potential conflicts with land areas on the Nellis Air Force Range, Timbisha Shoshone trust land parcel near Scottys Junction, Nevada, planned Ivanpah Valley regional airport, and wilderness study areas. If DOE decided to construct and operate a branch rail line in a rail corridor, it would avoid or mitigate any associated land use and ownership conflicts to implement the Proposed Action. However, additional conflicts associated with continued use of affected land areas could occur due to shipping operations being extended for 14 years beyond that of the Proposed Action.

The land required for the DOE low-level radioactive waste and Apex intermodal transfer stations would add to the approximately 0.21 square kilometer (50 acres) of property that would be required for the intermodal transfer station that would support the proposed Yucca Mountain Repository. The rail spur and facility for the low-level radioactive waste intermodal transfer station would disturb approximately 0.02 square kilometer (5 acres) of land. The Apex transfer facility would be in a building about 90 by 30 meters (300 by 100 feet). In addition, Apex would have a truck maintenance facility in a building about 30 by 18 meters (100 by 60 feet) that it could share with the low-level radioactive waste intermodal facility. The incremental impacts resulting from the changes in land use associated with the three intermodal transfer stations would not result in a substantial cumulative impact.

In addition to the cumulative changes in land use and ownership, DOE considered potential conflicts with plans and policies issued by various government entities along the alternative transportation corridors. In particular, DOE reviewed the Las Vegas 2020 Master Plan (DIRS 157274-City of Las Vegas 2001, all) and various other planning documents, including master plans for the Cities of Caliente (DIRS 157312-Sweetwater and Anderson 1992, all) and Alamo (DIRS 157275-Intertech and Sweetwater 1990, all), and the Lander County Revised Policy for Federally Administered Lands (DIRS 157310-Lander County 1999, all). The Las Vegas Master Plan provides broad policy direction for future land use decisions and related aspects in the City of Las Vegas through 2020. While the Alamo plan deals primarily with zoning issues, the Caliente plan discusses actions for dealing with potential population growth generated by the construction and operation of a repository at Yucca Mountain. The Caliente document generally expresses a need to annex lands that are contiguous to and south of the City in Meadow Valley Wash. The Caliente Intermodal Transfer Facility would be in Meadow Valley Wash (see Chapter 6, Figure 6-17). In general, local government policy indicates a goal of minimizing the conversion of private lands for public use. The transportation corridors and routes described in the EIS, particularly the rail corridors, were developed to minimize impacts to private lands. Section 6.3.2 discusses the amount of private land encountered along the rail corridors and a minimum-to-maximum range for each corridor, including variations and options. However, definitive information is not available on specific tracts of land that could be required for a specific transportation mode or route. Once DOE selected a transportation mode and a specific transportation corridor, more definitive information could be developed on potential conflicts with land uses and various agency plans and policies and, ultimately, the mitigation measures that could be needed to resolve conflicts and impacts on a given area.

8.4.2.2 Air Quality

Air quality cumulative impacts during construction of three intermodal transfer stations—one for intermodal transfers of casks containing spent nuclear fuel and high-level radioactive waste, one for intermodal transfers of low-level radioactive waste shipments to the Nevada Test Site, and one for intermodal transfers of Apex copper concentrate—would not be expected to occur since construction activities would likely occur at different times. The area in which the construction would occur is in attainment of the National Ambient Air Quality Standards and is outside of the Las Vegas Valley particulate matter (PM_{10}) and carbon monoxide nonattainment areas. Even if construction for all three intermodal transfer stations occurred concurrently, administrative controls would be implemented to prevent an adverse impact from collective emissions and dust-generating activities.

Emissions from all sources would be less than applicable standards for repository activities. Emissions would also be below established standards for a mostly legal-weight truck transportation scenario. For a mostly rail scenario, criteria pollutants would be emitted during earthmoving operations for branch rail line or intermodal transfer station and highway upgrade construction projects. Cumulative impacts would be greatest for activities occurring in the Las Vegas air basin, which is currently in nonattainment for particulate matter (PM_{10}) and carbon monoxide. For rail implementing alternatives, emissions into the Las Vegas air basin would exceed emission standards only for construction of a Valley Modified branch rail line. Emission standards could be exceeded by up to 90 percent for PM_{10} and up to 60 percent for carbon monoxide. Emissions from upgrading highways for a Caliente/Las Vegas heavy-haul truck route could also exceed standards for the Las Vegas air basin. PM_{10} emissions could slightly exceed the standard and carbon monoxide emissions could exceed the standard by 10 percent. All other activities would not cause emissions that exceeded emission standards.

During operations, there would be approximately one or two repository rail shipments and as many as 11 associated heavy-haul trucks a week, an average of about three trains and seven trucks a day for DOE low-level radioactive waste shipments, and one truck an hour for the Apex copper concentrate transport. At present, an average of one train an hour and light highway traffic travels through Caliente. The incremental increase in air pollutants from rail and highway traffic resulting from the three actions would cause slight, temporary increases in pollutants, but would not exceed Federal standards (Chapter 6, Section 6.3.2; DIRS 103225-DOE 1998, pp. 4-13, 5-4, and 5-8). Criteria pollutants released during routine operations of the intermodal transfer stations would include nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter. DOE expects these emissions would also be well within Federal standards.

8.4.2.3 Hydrology

Surface Water

Mitigation measures used during the construction of the intermodal transfer stations would minimize surface-water impacts. Floodplain impacts probably would occur if DOE selected the Caliente intermodal transfer station (see Appendix L). If that location was selected, DOE would conduct a detailed floodplain/wetland assessment and integrate good construction practices to minimize impacts. Construction probably would involve some permanent drainage alterations. Runoff rates would differ from natural or existing terrain but, given the relatively small size of the area, there would be little effect on overall runoff quantities for the area (Chapter 6, Section 6.3.3.1; DIRS 103225-DOE 1998, pp. 4-13 and 5-8). DOE expects very small impacts to surface waters during the construction and operation of the stations.

Groundwater

Construction activities for the intermodal transfer stations would disturb and loosen the ground for some time, which could result in higher infiltration rates. However, these activities and their resultant

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short-term impacts probably would occur at different times for the three stations. The relatively small sizes of the three facilities would minimize changes in groundwater infiltration rates during operations. Potential sources of contamination would include one to three diesel fuel tanks for the standby generators and heavy equipment for all three stations. The small overall water demand could be met by installing wells or by existing water distribution systems. In addition, the operation of the Apex copper concentrate and DOE low-level radioactive waste intermodal transfer station would only overlap with the beginning years of spent nuclear fuel and high-level radioactive waste shipment to the proposed Yucca Mountain Repository.

8.4.2.4 Biological Resources and Soils

The proposed locations of the intermodal transfer stations are in an irrigated pasture area that is partly wetland. However, because the area was modified as pasture and the native habitat has been degraded, cumulative impacts to biological resources would be low. Construction activities could lead to soil erosion. Water would be applied to suppress dust and compact soil. The operation of the stations would have small cumulative impacts on soils. Erosion damage control would be performed as necessary throughout the operational periods.

8.4.2.5 Cultural Resources

Cumulative impacts could occur to archaeological, historic, and traditional Native American cultural sites from the construction of the intermodal transfer stations. Cultural resource surveys of a portion of the Meadow Wash Area have identified two archaeological sites in the vicinity of the proposed Caliente DOE low-level radioactive waste intermodal site (DIRS 103225-DOE 1998, p. 4-13). Neither site falls within the proposed intermodal transfer station areas. However, Native American consultants have identified these archaeological sites as having significant cultural values for present-day Native American tribes, and construction and operation of the intermodal transfer station at this location could create a cumulative impact to these cultural values. DOE would perform ethnographic studies and archaeological surveys during the engineering design phases and before construction to identify these impacts and address their mitigation.

Impacts to cultural resources could occur along each of the candidate rail corridors where site file and literature searches have indicated a potential for archaeological, historic, and traditional cultural properties (see Chapter 3, Section 3.2.2.1.5). Some impacts to these resources could be cumulative, such the intersection of the National Historic Pony Express Trail by variations of the Carlin Corridor or the construction and operation of a branch rail line in Crescent Valley along the Carlin Corridor, where Native Americans believe that operations at the Cortez Mine have already had an impact on a Native American cemetery. After determining the mode of transportation and the preferred routing, DOE would undertake archaeological field studies and ethnographic evaluations of the corridor to identify further potential impacts and possible mitigative actions to reduce the effects of those impacts.

Some impacts associated with the use of existing highways could be cumulative, depending on the route selected. For example, Native American consultants have identified several places or areas along some of the highways that have cultural significance to regional tribes (see Chapter 3, Section 3.2.2.2.5). Heavy-haul truck traffic could have a cumulative adverse effect on the Goldfield National Register Historic District, although the potential for specific impacts to buildings in the historic district has yet to be fully evaluated. As with other potential components of the Nevada transportation scenario, DOE would complete additional archaeological, historical and ethnographic studies during the engineering design phase to identify and evaluate these types of potential impacts.

8.4.2.6 Socioeconomics

Employment levels for operation of the repository, Apex, and DOE low-level radioactive waste intermodal transfer stations would be 66, 25, and 14 employees, respectively (Chapter 6 and Section 8.1.2.2). Employment associated with the repository and low-level radioactive waste intermodal transfer stations includes operations personnel and truck drivers. Concurrent operations for all three stations would occur over a portion of the entire 24- or 38-year shipping period for the Proposed Action or Inventory Module 1 or 2, respectively. Employment levels would increase gradually to the maximum values listed above and then decrease gradually toward the end of emplacement activities for repository-related workers. Impacts to employment, population, personal income, Gross Regional Product, and state and local government expenditures during station operations would be small for Lincoln County (Chapter 6, Section 6.3.2.2; DIRS 103225-DOE 1998, pp. 4-14 and 5-9).

The truck traffic in the Caliente area would be increased from the three intermodal transfer stations. The small increase would have a very small impact on U.S. Highway 93, which would be used when entering and leaving the intermodal transfer station access road. U.S. 93 is currently characterized as having light traffic. The period of concurrent truck traffic from the three intermodal transfer stations would also occur only over a portion of the 24- or 38-year shipping duration for the Proposed Action or Inventory Module 1 or 2, respectively.

8.4.2.7 Occupational and Public Health and Safety

The incremental impacts resulting from an increase in radiological risk associated with the intermodal transfer stations for the repository and low-level radioactive waste shipments at Caliente would not result in a substantial cumulative impact. The estimated total collective worker dose from the entire DOE low-level radioactive waste intermodal shipping campaign, including transportation impacts, would be about 4.21 person-rem (DIRS 103225-DOE 1998, p. 4-10). This dose, added to the total repository intermodal transfer station and rail and heavy-haul truck shipments worker dose of about 2,200 to 3,300 person-rem for the Caliente intermodal transfer station for Inventory Module 1 or 2 (Appendix J, Table J-59) would be an increase of less than 1 percent. The population dose associated with low-level radioactive waste shipments by truck from the Caliente intermodal transfer station would be 7.55 person-rem for the entire shipping campaign (DIRS 103225-DOE 1998, Table C-11, p. C-23). This dose, added to the dose from shipments in Nevada that use heavy-haul trucks of about 600 person-rem over 38 years, would increase the population dose and associated health effects by less than 1 percent.

In addition to incremental impacts resulting from increases in radiological risk, there would be increments in nonradiological impacts of transportation in Nevada that are not included in the national impacts of transporting spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository. These increases would arise from 14 additional years of operating a branch rail line or of maintaining highways for use by heavy-haul trucks and operating an intermodal transfer station. The increments in nonradiological impacts for operation of a branch rail line would include increased traffic fatalities from worker commuting and the transportation of spent nuclear fuel and high-level radioactive waste, as well as repository materials. The increases would range from 0.45 to 1.1 fatalities (see Tables 6-78, 6-79, 6-85, 6-86, 6-93, 6-94, J-61, J-62, and J-63).

8.4.2.8 Noise

There would be an increase in noise levels at Caliente from any of the three candidate intermodal transfer station sites and the associated train switching operations and truck traffic. Noise levels would increase during daytime and night hours for rail activities and during daytime hours for truck shipment activities associated with the repository heavy-haul trucks and the DOE low-level radioactive waste trucks. Apex truck shipments would occur once an hour, 24 hours a day. Noise associated with railcar shipments would occur as the railcars were uncoupled from trains and transferred in and out of the stations, which could occur during the day or night. Elevated noise levels would occur during loading and unloading operations and briefly as trucks passed on the highway. Trucks would not travel through Caliente for shipments to either Yucca Mountain or the Nevada Test Site. Overall, the elevation of noise levels associated with rail and truck activity near a level that would cause concern would be unlikely. In addition, due to the location of the intermodal transfer stations in an uninhabited canyon area, noise impacts from rail and truck loading and unloading would be low. Cumulative effects would also be limited because operations at the DOE low-level radioactive waste and Apex intermodal transfer stations would overlap only a portion of the shipping campaign associated with the proposed repository.

Future development of the Timbisha Shoshone Trust Lands parcel near Scottys Junction could result in additional impacts. Residences and commercial ventures located near the transportation corridor on this parcel (the Bonnie Claire variation of the Caliente and Carlin rail corridors) could encounter noise levels that would not exceed 90 dB at 15 meters (49 feet) from the route.

8.4.2.9 Aesthetics

Chapter 6, Section 6.1.2.9 discusses direct impacts from the candidate rail corridors and heavy-haul truck routes. Section 6.3.2 discusses indirect visual impacts as they could affect land use along the rail corridors.

The alteration of the landscape immediately surrounding the Bureau of Land Management Class II lands [within about 8 kilometers (5 miles) of the Kershaw-Ryan State Park] could exceed the Class II objective. In addition, the Wilson Pass Option in the Jean Corridor passes through Class II lands [55 kilometers (34 miles)] in the vicinity of Wilson Pass in the Spring Mountains. Class II designation by the Bureau of Land Management could require retention of the existing character of the landscape. However, the area proposed for the Caliente intermodal transfer station has been classified as Class III, which would require partial retention of the existing character of the landscape. The intermodal facilities would not greatly alter the landscape more than the current passing trains and sewage treatment operations. The Class II lands of the Wilson Pass Option would require retention of the existing character of the landscape. Public exposure would be limited due to obstruction by natural vegetation. Therefore, visual impacts would be very small (DIRS 103225-DOE 1998, pp. 4-12 and 5-8).

8.4.2.10 Utilities, Energy, and Materials

Electric power lines with adequate capacity are available near the site. Electric power, water supply, and sewage disposal facilities are currently provided to the sewage treatment facility near the proposed location of the intermodal transfer stations (DIRS 103225-DOE 1998, p. 4-12). Therefore, cumulative impacts to utilities would be small. The quantities of concrete, asphalt, and steel needed to build the intermodal facilities (associated mostly with the repository intermodal transfer station) would be unlikely to affect the regional supply system.

8.4.2.11 Management of Intermodal Transfer Station-Generated Waste and Hazardous Materials

The expected quantities of sanitary waste, small amounts of hazardous waste, and low-level radioactive waste associated with radiological surveys would be unlikely to have large impacts to landfill, treatment, and disposal facilities available for use by this site. Therefore, cumulative impacts for waste management would be small. Only limited quantities of hazardous materials would be needed for station operations, and DOE does not expect these needs to affect the regional supply system (DIRS 103225-DOE 1998, pp. 4-12, 4-13, and 5-8).

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8.4.2.12 Environmental Justice

Because there would be no large cumulative impacts to human health and safety from the construction or operation of the intermodal transfer stations, there would be no disproportionately high and adverse impacts to minority and low-income populations. The absence of large cumulative environmental impacts for the general population means that there would be no disproportionately high and adverse environmental impacts for the minority or low-income communities. An evaluation of subsistence lifestyles and cultural values confirms these general conclusions. The foregoing conclusions and evaluations and the commitment by DOE to ensure minimal impacts to cultural resources show that construction and operation of the intermodal transfer stations would not be expected to cause or contribute to disproportionately high and adverse impacts to Native Americans (DIRS 103225-DOE 1998; pp. 4-14 and 5-9).

8.5 Cumulative Manufacturing Impacts

This section describes potential cumulative environmental impacts from the manufacturing of the repository components required to emplace Inventory Module 1 or 2 in the proposed Yucca Mountain Repository. No adverse cumulative impacts from other Federal, non-Federal, or private actions have been identified because no actions have been identified that, when combined with the Proposed Action or Inventory Module 1 or 2, would exceed the capacity of existing manufacturing facilities.

The overall approach and analytical methods and the baseline data used for the evaluation of cumulative manufacturing impacts for Inventory Module 1 or 2 were the same as those discussed in Chapter 4, Section 4.1.15 for the Proposed Action. The evaluation focused on ways in which the manufacturing of the repository components could affect environmental resources at a representative manufacturing site and potential impacts to material sources and supplies.

Table 8-59 lists the total number of repository components required for the Proposed Action and Inventory Modules 1 and 2. As listed, the total number would increase by approximately 30 to 50 percent for Modules 1 and 2 in comparison to the Proposed Action depending on the operating mode and packaging scenario. The highest total number of repository components would be for Module 2, assuming the lower-temperature operating mode using derated waste packages, and this was the number used in the cumulative impact analysis.

Based on the total number of components that would be required over a 38-year period for Inventory Module 1 or 2, the annual manufacturing rate would remain the same as that for the Proposed Action.

Based on the number of drip shields required over a 12-year period for Inventory Module 1 or 2, the annual manufacturing rate would increase about 30 percent over that for the Proposed Action 10-year drip shield manufacturing period.

Thus, the annual Module 1 or 2 impacts for air quality, socioeconomics, material use, and waste generation would be as much as 30 percent higher than those for drip shield manufacturing discussed in Chapter 4, Section 4.1.15 for the Proposed Action, and these impacts would continue for 12 years rather than the 10 years for the Proposed Action. The total number of worker injuries and illness or fatalities would increase in proportion to the increase in components manufactured. The potential number of injuries and illnesses over the entire 50-year period for Module 1 or 2 would be from 930 to 1,300 and the estimated number of fatalities would be 0.44 to 0.63 (that is, no expected fatalities), depending on the operating mode and packaging scenario. As for the Proposed Action, there would be few or no impacts on other resources because existing manufacturing facilities would meet the projected manufacturing needs and new construction would not be necessary and environmental justice impacts (that is, disproportionately high and adverse impacts to minority or low-income populations) would be unlikely.

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Table 8-59. Number of offsite-manufactured components required for the Proposed Action and Inventory Modules 1 and 2.

		Operating mode/packaging scenario								
		Proposed Action			Module 1			Module 2		
		UC	C	UC/C[a]	UC	C	UC/C[a]	UC	C	UC/C[a]
Component	Description	HT		LT	HT		LT	HT		LT
Disposal containers	Containers for disposal of SNF[a] and HLW[a]	11,300	11,300	11,300 - 16,900	16,650	16,650	16,650 - 25,350	17,250	17,250	17,250 - 26,000
Rail shipping casks or overpacks	Storage and shipment of SNF and HLW	0	120	0 - 120	0	152	0 - 197	0	157	0 - 202
Legal-weight truck shipping casks	Storage and shipment of uncanistered fuel	120	8	8 - 120	227	13	13 - 227	241	13	13 - 241
Drip shields	Titanium cover for a waste package	10,500	10,500	11,300 - 15,900	15,600	15,600	16,650 - 23,400	16,300	16,300	17,250 - 24,700
Emplacement pallet	Support for emplaced waste package	11,300	11,300	11,300 - 16,900	16,650	16,650	16,650 - 25,350	17,250	17,250	17,250 - 26,000
Solar panels[b]	Photovoltaic solar panels–commercial units	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000
Dry storage cask shells[c]	Metal shell structure of storage vault for aging	0	0	0 - 4,000	0	0	0 - 4,000	0	0	0 - 4,000

a. UC = uncanistered packaging scenario; C = canistered; HT = higher-temperature operating mode; LT = lower-temperature operating mode; SNF = spent nuclear fuel; HLW = high-level radioactive waste.

b. Number of panels in use at any one time.

c. Necessary only if DOE used surface aging as part of a lower-temperature operating mode.

8.6 Summary of Cumulative Impacts

As shown throughout Chapter 8, DOE has examined many actions in the region to determine the potential for cumulative impacts. These impacts could arise from a variety of sources, including other activities in the area and reasonably foreseeable activities.

Table 8-60 summarizes cumulative impacts from all origins. Where qualitative descriptions are more meaningful, these have been included in lieu of quantitative values, although the quantitative values might be provided in this chapter. In other cases, the quantitative values have been provided to give a better representation of the potential impacts.

Table 8-60. Summary of cumulative impacts presented in Chapter 8 (page 1 of 2).

Discipline area	Cumulative impact
Land use and ownership	About 600 square kilometers (150,000 acres) of land would be withdrawn for the repository, but land is already under Federal control. Other actions in the area would cause additional withdrawals, but some land would also be returned under the Southern Nevada Public Land Management Act. Overall, total land withdrawal analyzed in this EIS is less than 0.5 percent of total Federal lands in Nevada.
Air quality	*Nonradiological:* Emissions from all sources would be less than applicable standards for repository activities. Emissions would also be below established standards for a mostly legal-weight truck transportation scenario. For a mostly rail scenario, criteria pollutants would be emitted during earthmoving operations for branch rail line or intermodal transfer station and highway upgrade construction projects. Cumulative impacts would be greatest for activities occurring in the Las Vegas air basin, which is currently in nonattainment for particulate matter (PM_{10}) and carbon monoxide. For rail implementing alternatives, emissions into the Las Vegas air basin would exceed emission standards only for construction of a Valley Modified branch rail line. Emission standards could be exceeded by up to 90 percent for PM_{10} and up to 60 percent for carbon monoxide. Emissions from upgrading highways for a Caliente/Las Vegas heavy-haul truck route could also exceed standards for the Las Vegas air basin. PM_{10} emissions could slightly exceed the standard and carbon monoxide could exceed the standard by 10 percent. All other activities would not cause emissions that exceeded emission standards.
	Radiological: Short-term air emissions from nearby facilities would result in a dose to the maximally exposed individual of no greater than 2.5 millirem per year. Emissions from past nuclear weapons testing could have resulted in a dose of 150 millirem over the lifetime of those individuals exposed during atmospheric weapons testing. Long-term atmospheric releases from the Nevada Test Site and Beatty Low-Level Waste Facility are not expected to result in a dose greater than 0.007 millirem per year in the future.
Hydrology	*Surface Water:* Cumulative impacts on surface water quality are not expected because of the transient nature of the surface water bodies around the repository. Minor changes to runoff and infiltration rates could occur. Construction of access routes at the repository site could have minor and localized effects on several washes at Yucca Mountain. Elsewhere in Nevada, routes being considered for the movement of waste to Yucca Mountain would pass through or near floodplains and wetlands and would be assessed in more detail once a route is selected.
	Groundwater: Groundwater demands from the repository are below the perennial yield of the western two-thirds of the Jackass Flats basin. When combined with Nevada Test Site activities, the annual water withdrawal (600 acre-feet) could exceed the lowest estimate of perennial yield but would not exceed highest estimate of perennial yield. No short-term impacts to groundwater quality are expected. Long-term impacts to groundwater could be as high as 0.007 millirem per year under the conservative assumption that impacts from the Nevada Test Site and the repository overlap spatially and chronologically.
Biological resources and soils	Disturbance of desert tortoise habitat would occur. Wildlife would be displaced as a result of repository and transportation activities that used additional land in the region. Little or no loss of wetland habitat is expected. No expected impacts to any species.
Cultural resources	Adverse impacts to cultural resources are not expected. Potential for encountering cultural resources exists along transportation corridors. DOE would use practices to avoid or mitigate adverse impacts in these areas.
Socioeconomics	As many as 3,400 direct jobs during peak employment year from repository activities. Intermodal transfer station or rail line in Lincoln County could change employment estimates by 5 percent.

Table 8-60. Summary of cumulative impacts presented in Chapter 8 (page 2 of 2).

Discipline area	Cumulative impact
Occupational and public health and safety	*Nonradiological:* Repository activities, including transportation, could result in up to 37 fatalities[a] from construction to closure of the repository. *Radiological:* Radiation exposure could result in up to 32 latent cancer fatalities[a] to workers. Short-term radiation exposure to the public could result in up to 5 latent cancer fatalities[a] in the population. Short-term radiation exposure to the maximally exposed individual could cause an increased cancer risk of about 1.2×10^{-6}. Emissions from past nuclear weapons testing could have caused an increased risk of about 7.5×10^{-5} for affected individuals. Long-term releases from the repository and other actions in the area could cause an increased risk of fatal cancer in the future of 0.000006 over the lifetime of an exposed individual.
Noise	Noise levels would be transient and would not be expected to cause adverse impacts for repository operation. Future development of the Timbisha Shoshone Trust Lands near Scottys Junction could result in residents of that parcel being subjected to transient noise from a candidate rail corridor through the parcel.
Aesthetics	Placement of exhaust stacks on top of Yucca Mountain could impact visual resources because stacks would be visible from some distance. If the stacks were equipped with beacons, the visual effect would be more noticeable at night. Disturbed areas would be likely on former Federal lands that are used for commercial and private purposes. Acquisition of private lands by the Federal Government could result in reduced aesthetics impacts and possible return of land to natural state.
Utilities, energy, materials, and site services	Peak electrical power demand would require upgrade to electrical transmission and distribution system. Other site systems and nearby suppliers of materials would be sufficient to meet repository and transportation needs. Construction of electrical generating facilities in the region surrounding the repository would increase the electrical generating capacity for the area.
Waste management	If nonradioactive, nonhazardous solid waste was disposed of at the Nevada Test Site, existing landfills would need to be expanded. Other waste types could be disposed of at nearby facilities without exceeding capacities of those facilities.
Environmental justice	No disproportionately high and adverse cumulative impacts to minority or low-income populations would occur for repository, transportation, or other activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the proposed repository, and that implementing the Proposed Action would continue restrictions on access to the proposed site.

a. These values represent the maximum for each environmental resource area. Because the maximum could occur for different implementing alternatives in the various resource areas, simple addition of these maximums could overstate the impacts due to mixing of incompatible alternatives.

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Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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9

Management Actions To Mitigate Potential Adverse Environmental Impacts

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9. MANAGEMENT ACTIONS TO MITIGATE POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

This chapter describes management actions that the U.S. Department of Energy (DOE or the Department) is considering to reduce or mitigate adverse impacts to the environment that could occur if the Department implemented the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. In keeping with previous chapters in this environmental impact statement (EIS), this chapter contains separate discussions for the mitigation of repository impacts and the mitigation of impacts from transportation activities. Mitigation includes activities that (1) avoid the impact altogether by not taking a certain action or parts of an action; (2) minimize impacts by limiting the degree or magnitude of the action and its implementation; (3) repair, rehabilitate, or restore the affected environment; (4) reduce or eliminate impacts over time by preservation or maintenance operations during the life of the action; or (5) compensate for the impact by replacing or substituting resources or environments.

This chapter also describes mitigations in environmental resource areas where DOE has identified adverse impacts and analysis has indicated that mitigation has the potential to reduce those impacts. This chapter does not discuss mitigations for environmental resource areas for which analyses have not identified a potential for impacts.

Changes in repository design have resulted in modifications to some planned or potential mitigation measures identified in the Draft EIS. In addition, DOE has identified some new mitigation measures.

Apart from the impact findings and mitigations discussed in this EIS, Section 116(c) of the Nuclear Waste Policy Act, as amended (NWPA) states that "the Secretary shall provide financial and technical assistance to (an affected unit of local government or the State of Nevada)… to mitigate the impact on such (an affected unit of local government or the State of Nevada) of the development of (a) repository and the characterization of (the Yucca Mountain) site." Such assistance can be given to mitigate likely "economic, social, public health and safety, and environmental impacts." Within that broad framework, neither Section 116 nor any other provision of the NWPA limits the impacts that are subject to assistance under Section 116 to the environmental impacts considered in this EIS.

The fact that the EIS analysis has determined that the implementation of the Proposed Action would not cause substantial socioeconomic impacts to communities in Nevada or to the State of Nevada does not prevent local governments or the State government from receiving assistance to address economic, social, public health, or environmental impacts under Section 116(c).

The Section 116 impact assistance review process and the Yucca Mountain Repository EIS process are distinct from one another, and the implementation of one would not depend on the implementation of the other. The provision of assistance under Section 116 would not necessarily be limited either by the impacts identified in this EIS or by its findings on such impacts. Any decision to provide assistance under Section 116 will be based on an evaluation of a report submitted by an affected unit of local government or the State of Nevada pursuant to Section 116 to document likely economic, social, public health and safety, and environmental impacts.

9.1 Types of Management Actions

The design, construction, operation and monitoring, and closure planning for the proposed repository incorporate physical features, procedures, and safeguards to reduce environmental consequences. Some of these features, procedures, and safeguards are the result of DOE determinations based on site characterization activities and the ongoing evaluation of planning and design for the proposed repository.

To complement the measures already incorporated, DOE is considering a range of additional mitigation measures aimed at reducing consequences of the proposed repository project. The repository and transportation mitigation analyses in this chapter discuss impact reduction measures that DOE expects to implement as well as other mitigations DOE is considering.

9.1.1 DOE-DETERMINED IMPACT REDUCTION FEATURES, PROCEDURES, AND SAFEGUARDS

DOE has studied the Yucca Mountain site, vicinity, and regions of influence for more than a decade and has accumulated considerable knowledge. The Department has identified many improvements in its project design and plan to reduce potential impacts. The Proposed Action includes commitments to reduce impacts that DOE has made as a result of its site characterization studies and the ongoing evaluation of repository planning and design. DOE would undertake these measures if the Secretary of Energy recommended the site for development and authorization was provided to proceed with the Proposed Action. This chapter identifies these commitments in appropriate areas.

9.1.2 MITIGATION MEASURES UNDER CONSIDERATION FOR INCLUSION IN PROJECT PLAN AND DESIGN

DOE has conducted extensive site characterization studies, and continues to evaluate whether to commit to additional mitigation measures in the event the site is designated and the Nuclear Regulatory Commission grants a license for the repository project. DOE is considering these additional measures to reduce the potential effects of the repository project. This chapter identifies measures under consideration in appropriate subject areas.

9.1.3 ONGOING STUDIES THAT COULD INFLUENCE MITIGATION MEASURES IN THE PROJECT PLAN AND DESIGN

Accelerator Transmutation of Waste technology has been under consideration for many years as a process for the treatment of nuclear waste. This technology would involve the use of a chemical separation process, a linear accelerator, and a subcritical nuclear assembly. The chemical process would separate transuranic and certain long-lived radioisotopes from the spent nuclear fuel. The linear accelerator and subcritical nuclear assembly would change the transuranic and long-lived radioisotopes into short-lived radioisotopes and stable (nonradioactive) elements.

The National Research Council studied Accelerator Transmutation of Waste and other technologies for use in the treatment of spent nuclear fuel (DIRS 103403-National Research Council 1996, all). The study concluded that:

- The use of separation and transmutation to treat spent nuclear fuel is technically feasible.
- Treatment would cost many tens of billions of dollars and require many decades to implement.
- While other technologies would be based on considerable experience, Accelerator Transmutation of Waste technology would require extensive development before DOE could realistically assess its technical feasibility.
- No separation and transmutation technology offers sufficient promise to abandon current spent nuclear fuel management programs or delay the opening of the first nuclear waste repository.
- Even with a successful separation and transmutation program, a monitored geologic repository would still be necessary because the process would be unlikely to provide perfect transmutation, in which

case there would be residual materials requiring long-term isolation from human populations and concentrations of human activity.

- Separation and transmutation technology might delay or eliminate the need for a second repository, but there are legislative and less expensive technical ways to increase the capacity of the first repository by an equivalent amount.

In the Fiscal Year 1999 Energy and Water Appropriation Act, Congress directed DOE to conduct an Accelerator Transmutation of Waste study and to prepare a plan for the development of this technology in Fiscal Year 1999. In October 1999, DOE submitted to Congress *A Roadmap for Developing Accelerator Transmutation of Waste (ATW) Technology* (DIRS 110625-DOE 1999, all). Key elements of the report include:

- The identification of technical issues requiring resolution
- The delineation of a 6-year science-based program to begin addressing resolution of technical issues
- If technical issues are resolved, a research and development plan for construction of a demonstration facility to become operational in 2035
- If research and development are successful, a production plan for transmutation of 79,000 metric tons (87,000 tons) of civilian waste over 90 years
- A listing of possible collaborative efforts with other countries
- The identification of institutional challenges of an Accelerator Transmutation of Waste program
- A discussion of possible benefits to other programs
- An estimate of the life-cycle costs for transmutation and processing of the currently projected inventory of civilian spent nuclear fuel

The report conclusions include the following:

- The implementation of Accelerator Transmutation of Waste technology will require years of additional research.
- The implementation of Accelerator Transmutation of Waste technology would require a significant investment in research and development funding.
- Accelerator Transmutation of Waste is technically feasible, but it would require billions of dollars and many decades to fully construct and operate a transmutation facility, and it would not eliminate the need for a repository.
- Complex institutional and public acceptance issues regarding the technology would have to be resolved.

A successful Accelerator Transmutation of Waste program would last approximately 117 years and would cost at least $281 billion dollars. Such a program could reduce the radioactivity of commercial waste by a factor of 10 to 100.

Since the October 1999 publication of the Accelerator Transmutation of Waste Roadmap, DOE's transmutation research and development program has undergone significant changes. It is currently managed as an Advanced Accelerator Applications program, with the goal of evaluating the technical feasibility of nuclear waste transmutation using a broader technology base than was covered by the earlier Roadmap. A general description of the modified program was presented in *The Advanced Accelerator Applications Program Plan* on March 30, 2001 (DIRS 156711-DOE 2001, all).

Among other aspects of the program, the plan discusses the proposed design and operation of an Accelerator Driven Test Facility as part of a research and development program that would evaluate combinations of critical and subcritical transmutation systems. These have the potential for utilizing the strengths of each transmutation technology in combination, the effectiveness of which is expected to be greater than either taken separately. A revised roadmap describing the program's new directions is currently being prepared.

The elimination or reduction of certain radionuclides in the disposal inventory could add flexibility to the design of the repository and reduce uncertainties about its performance. DOE will incorporate information from any future studies in its decisions during the preparation of a Mitigation Action Plan for this EIS and during the repository licensing process, if those became necessary.

9.1.4 MITIGATION ACTION PLAN

To minimize potential impacts from the Proposed Action (if the repository site was designated), DOE is evaluating the preparation of a Mitigation Action Plan containing specific commitments for mitigating adverse environmental impacts associated with the Proposed Action. The plan would describe specific actions DOE would take to implement mitigation commitments and would reflect available information about the course of action. DOE could revise this Plan as more specific and detailed information became available.

The Mitigation Action Plan would incorporate all practicable measures to avoid or minimize adverse environmental and human health impacts that could result from the implementation of the Proposed Action. The Plan would contain:

1. An introduction describing the basis, function, and organization of the Plan
2. A summary of the impacts to be mitigated
3. A statement of mitigation goals, objectives, and performance standards
4. A description of specific mitigation actions
5. A description of the Mitigation Action Plan monitoring and reporting system that DOE would implement to ensure that elements of the Plan were met

Precise mitigation measures cannot be identified at present. For example, transportation route selection decisions would affect the potential for impacts to areas of importance to Native Americans, to local communities, or to the general environment; repository or transportation corridor construction activities could reveal new cultural resource sites. DOE would consult with Native American tribes and local governments in developing the Mitigation Action Plan. If activities associated with the Proposed Action could affect specific sacred or ceremonial areas or resources or other areas of importance, DOE could develop procedures for controlled access as long as project integrity was not compromised.

DOE would prepare the Mitigation Action Plan in compliance with applicable regulations. The Plan would accompany any License Application to the Nuclear Regulatory Commission.

9.1.5 MONITORING

DOE would conduct the following monitoring activities during all phases of the project to ensure the implementation of the Proposed Action as described and to ensure mitigation of impacts:

- Continue the performance confirmation program which consists of tests, experiments, and analyses, during all phases of the repository project to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the repository would meet the performance objective for the period after permanent closure.

- Monitor groundwater quality, air emissions, and the repository workplace to ensure project worker safety and other aspects of project interaction with the natural and human environment during the construction, operation and monitoring, and closure phases of the project.

- Conduct cultural resources monitoring activities as appropriate before and during surface disturbance activities to identify and assess the potential for impacts to previously unidentified archaeological resources.

- Conduct monitoring and reporting activities to ensure the implementation and effectiveness of mitigation measures and to ensure in general the accomplishment of the elements of the Mitigation Action Plan.

- Monitor material emplaced in the repository starting with the first emplacement of waste packages and continuing through closure.

- After the completion of emplacement, continue to monitor and inspect waste packages and continue performance confirmation activities.

- After sealing the repository openings, conduct postclosure monitoring to ensure acceptable repository performance. Details of this program would be defined during processing of the license amendment for repository closure rather than now to take advantage of appropriate technology, including technology that might not be currently available.

9.2 Yucca Mountain Repository

This section discusses mitigation measures DOE has determined it would implement, or has identified for consideration, to reduce potential impacts from the construction, operation and monitoring, and eventual closure of the proposed repository.

9.2.1 LAND USE

The Yucca Mountain site is remote and is partly withdrawn for specific Federal uses. The permanent withdrawal of land for the repository would prevent public use of the withdrawn lands for other purposes.

Land Use Measures Under the Proposed Action

- Reclaim lands disturbed during the construction process and not required for permanent use by the repository and surface support facilities.

9.2.2 AIR QUALITY

Construction and operation activities such as vehicle movement, clearing, grading, rock pile maintenance, and excavating could generate substantial quantities of fugitive dust. Standard mitigation measures could reduce dust emissions from fugitive dust-generating activities at the Yucca Mountain site. Other dust-generating sources such as operation of the concrete batch plant and backfill preparation facilities would be comparatively small contributors. DOE expects concentrations of other criteria pollutants to be less than 1 percent of regulatory limits (see Chapter 4, Section 4.1.2). Activities that would generate other criteria pollutants include the operation of internal combustion engines in construction equipment, boiler operation, and similar devices, along with limited emissions of radionuclides.

Air Quality Measures Under the Proposed Action

- Reduce fugitive dust emissions using standard dust control measures routinely applied during construction projects including, for example, routine watering of unpaved surfaces; wet suppression for material storage, handling, and transfer operations; and wind fences to control windblown dust. The efficiency of these controls tends to vary depending on site characteristics, but it ranges from a 60- to 80-percent reduction in fugitive dust emissions (DIRS 103676-Cowherd, Muleski, and Kinsey 1988, p. 5-22).

- Reduce maximum fugitive dust concentrations with working controls such as scheduling construction operations to minimize concurrent generation by activities that were near each other (for example, conducting adjacent clearing and grading activities at different times).

- High-efficiency particulate air filters and modern facility design to minimize the potential for airborne contamination.

9.2.3 HYDROLOGY

This section describes potential mitigation measures for surface water and groundwater.

9.2.3.1 Surface Water

Potential impacts to surface water from the construction, operation and monitoring, and eventual closure of the proposed repository would fall into the following categories: (1) introduction of contaminants, (2) alteration of drainage either by changing infiltration and runoff rates or channel courses, and (3) flood hazards. Changes in infiltration and runoff rates could alter flow rates in channels, cause ponding, and increase erosion. DOE expects such impacts to be minimal (see Chapter 4, Section 4.1.3). Nevertheless, the mitigation of impacts could produce such benefits as erosion control and pollution prevention.

Flash floods could spread contamination from accidental spills. Design and operational controls could mitigate the potential for contamination of surface water from accidental releases of radiological or hazardous constituents. DOE's intent would be to respond rapidly with appropriate cleanup actions.

Surface-Water Measures Under the Proposed Action

- Minimize disturbance of surface areas and vegetation, thereby minimizing changes in surface-water flow and soil porosity that would change infiltration and runoff rates.

- Mitigate flood hazards by designing facilities to withstand or accommodate a 100-year flood, and by designing facilities that would manage radiological materials to withstand the calculated probable maximum flood.

- Minimize physical changes to drainage channels by building bridges or culverts where roadways would intersect areas of intermittent water flow. Use erosion and runoff control features such as proper placement of pipe, grading, and use of rip-rap at these intersections to enhance the effectiveness of the bridges or culverts.

- Maintain natural contours to the maximum extent feasible, stabilize slopes, and avoid unnecessary offroad vehicle travel to minimize erosion.

- In and near floodplains, follow reclamation guidelines (DIRS 102188-YMP 1995, all) for site clearance, topsoil salvage, erosion and runoff control, recontouring, revegetation, siting of roads, construction practices, and site maintenance.

- Implement best management practices, including training employees in the handling, storage, distribution, and use of hazardous materials, to provide practical prevention and control of potential contamination sources.

- Conduct fueling operations and store hazardous materials and other chemicals in bermed areas away from floodplains to decrease the probability of an inadvertent spill reaching the floodplains.

- Provide rapid response cleanup and remediation capability, techniques, procedures, and training for potential spills.

- Use sediment-trapping devices such as hay or straw bales, fabric fences, and devices to control water flow and discharge to trap sediments moved by runoff.

Surface-Water Measures Under Consideration

- Use physical controls such as secondary containment for fuel storage tanks to reduce the potential for releases to mingle with stormwater runoff.

9.2.3.2 Groundwater

Impacts to groundwater from the proposed repository could include introduction of contaminants and alteration of infiltration and runoff rates that could change the rate of recharge to the aquifer. Design and operational actions to reduce such impacts for the active life of the repository and the alteration of infiltration and runoff rates would be identical to those described above for surface-water impacts.

The purpose of proposing a monitored geologic repository is to provide a natural setting that, with engineered repository and waste package barriers, would provide long-term confinement and isolation of spent nuclear fuel and high-level radioactive waste. Two aspects of groundwater analysis—(1) the ability of the repository and the engineered barriers to keep waste packages isolated from groundwater over time, and (2) the extent to which groundwater could become contaminated with radionuclides from breached waste packages and transport radionuclides to places where human exposure could occur—are central elements in determining the potential for a proposed repository to succeed.

DOE’s detailed study of the Yucca Mountain site has resulted in the inclusion of many engineered barrier elements to complement the site’s natural characteristics to keep unsaturated zone groundwater from reaching and transporting radionuclides and, thereby, to reduce the long-term potential for impacts. The following summarizes the engineered barrier elements that would contribute to a reduction of the long-term potential for impacts from radionuclides isolated in a Yucca Mountain Repository.

Groundwater Measures Under the Proposed Action

- The Yucca Mountain site has several characteristics (as described in Chapter 3) that indicate a high potential for reducing possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste, including:
  - The Yucca Mountain vicinity is isolated from concentrations of human population and human activity and is likely to remain so.
  - The climate is arid and conducive to evapotranspiration, resulting in a relatively small volume of water that has the capability to move as groundwater within the unsaturated zone of the mountain.
  - The groundwater table is substantially below the level at which DOE would locate a repository, providing additional separation from materials emplaced in waste packages.
  - The sparsely populated hydrogeologic basin into which groundwater from Yucca Mountain flows is closed, providing a barrier to a general spread of radionuclides in the event waste packages were breached and radionuclides reached groundwater.
- Use performance confirmation measures to detect any departure from expected capability of the repository in confining and isolating waste.
- Recycle water collected in subsurface areas for use in dust suppression and other activities, to minimize water consumption.
- Implement measures to minimize the potential for water used during operations to interfere with waste isolation in the repository.
- Minimize surface disturbance, thereby minimizing changes in surface-water flow and soil porosity that could change infiltration and runoff rates.
- Use corrosion-resistant waste packages and other engineered barriers, such as drip shields, to prevent water intrusion.
- Monitor to detect and define unanticipated spills, releases, or similar events.
- Evaluate scenarios to minimize the potential for different heat levels to have a direct effect on corrosion rates and the integrity of containers, as well as on the hydrology, geochemistry, and stability of the drifts. High levels could indirectly affect general groundwater flow and the transport of radionuclides.
- Use stainless-steel-lined concrete basins that include leak detection systems, pool cleanup equipment, and transfer equipment capable of moving waste in the event of a leak, and that are designed to seismic standards to minimize the potential for leaks in fuel transfer and holding pools located inside surface facilities.
- Use drip shields to deflect water migrating downward through the unsaturated zone to waste emplacement areas.

9.2.4 BIOLOGICAL RESOURCES AND SOILS

Potential impacts to biological resources and soils from repository construction, operation and monitoring, and closure could result from land clearing, vehicle movement, materials placement, trenching and excavation, and accidents. This section discusses the potential mitigation of impacts that could affect the desert tortoise and biological resources and soils in general.

9.2.4.1 Desert Tortoise

The desert tortoise is the only Federally protected species that resides on the site of the proposed repository (see Chapter 3, biology sections). Activities that could cause impacts to desert tortoises include site clearing, vehicle traffic, pond management, and taking of habitat. Since 1990, DOE has been conducting site characterization activities in accordance with Fish and Wildlife Service biological opinions on the potential for impacts to desert tortoises (DIRS 104618-Buchanan 1997, pp. 1 and 2). During these activities, five desert tortoises are known to have been killed by site characterization activities, all by vehicle traffic. A recent report (DIRS 103194-CRWMS M&O 1998, p. 9) indicates that 27 of 28 tortoise relocations were successful and that two nest relocations were also successful. The one unsuccessful relocation involved a tortoise that returned to the area of disturbance and became one of those killed by traffic.

DOE submitted to the U.S. Fish and Wildlife Service a biological assessment of the effects of construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain. The U.S. Fish and Wildlife Service has produced a Final Biological Opinion on the effects of construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain (see Appendix O). The Final Biological Opinion establishes conditions for repository construction, operation and monitoring, and eventual closure as well as for the remaining site activities prior to repository construction (if the site was approved). The Final Biological Opinion does not evaluate effects that could occur to the desert tortoise from the construction of transportation infrastructure and transportation of materials.

In its Final Biological Opinion, the U.S. Fish and Wildlife Service lists five reasonable and prudent measures to minimize impacts to the desert tortoise, and then lists 18 terms and conditions with which DOE must comply to implement the five measures. The Final Biological Opinion states reporting requirements upon the location of an injured or dead desert tortoise and conservation recommendations to minimize or avoid adverse effects on listed species or critical habitat. If the repository was authorized, DOE would observe and implement all terms and conditions, reporting requirements, and conservation recommendations that the U.S. Fish and Wildlife Service has established in its Final Biological Opinion to protect the desert tortoise. DOE expects to observe and implement all terms and conditions, reporting requirements, and conservation recommendations in any future biological opinions regarding the effects of transportation or other project activities on the desert tortoise or other listed species.

As discussed in Chapter 4, the proposed repository location is at the extreme northern edge of the range of the desert tortoise, and the population of tortoises at that location is small in relation to other portions of its range. No part of the repository location has been declared critical habitat for the desert tortoise.

Desert Tortoise Measures under the Proposed Action

DOE adopts all impact reduction measures and all terms and conditions established by the U.S. Fish and Wildlife Service to protect the desert tortoise.

The following text summarizes the five reasonable and prudent measures established in the U.S. Fish and Wildlife Service's Final Biological Opinion (see Appendix O), and identifies the terms and conditions that the Biological Opinion has set forth to implement each reasonable and prudent measure:

1. Minimize take of desert tortoises due to project-related activities and operation of heavy equipment

- A qualified biologist would conduct clearance surveys for tortoises before vegetation removal or soil disturbance of more than 0.02 square kilometer (5 acres) or when records indicated that tortoises could occur in the area to be disturbed. Project activity would be moved if there was an adjacent area free of tortoises on which the activity could be conducted. If no suitable site was available, the biologist would determine the site having the smallest impact on tortoises and their habitat.

- The biologist would conduct 100 percent coverage clearance surveys the day before or the day of surface-disturbing activity, during the tortoise activity season, and within 7 days before surface-disturbing activity during hibernation. If tortoises or eggs were found, they would be moved pursuant to U.S. Fish and Wildlife Service guidelines. Burrows would be conspicuously flagged and avoided by at least 9 meters (30 feet).

- Unavoidable burrows would be inspected. If unoccupied, burrows would be collapsed to prevent tortoise entry. If tortoises or eggs were present, they would be excavated by hand and moved.

- If removed from a burrow, a tortoise would be placed in the shade of a shrub or an existing, similar, unoccupied burrow. A tortoise moved when in hibernation, estivation, or brumination (dormant states due to heat or cold) would be placed in an adequate unoccupied or constructed burrow.

- Project activities that could endanger a tortoise would cease if a tortoise was found on a project site and would not resume until after the tortoise moved or was moved out of danger by the biologist.

- A desert tortoise biologist or environmental monitor would be at the site during all phases of construction to ensure compliance with the Biological Opinion and to protect tortoises from harm. The environmental monitor would be responsible for: (1) enforcing the litter-control program; (2) ensuring that tortoise-proof fences were maintained; (3) ensuring that tortoise habitat disturbance was restricted to authorized areas; (4) ensuring storage of all equipment and materials within construction zones or previously disturbed areas; (5) ensuring that all vehicles used existing graded or paved roads or stayed within construction zones; (6) ensuring inspection of open trenches and other excavations; (7) ensuring that speed limits were observed; and (8) ensuring compliance with all terms and conditions of the Biological Opinion. Environmental monitors would not be authorized to handle tortoises.

- Vehicles would not be driven off existing roads in nonemergency situations unless authorized by DOE. Vehicle paths would be cleared of tortoises pursuant to terms of the Biological Opinion.

- Vehicles would be driven at speeds within posted limits on existing roads, and would not exceed 40 kilometers (25 miles) per hour on unposted roads.

- DOE would continue to present a tortoise education program to all employees on the project site and would address specific issues identified in the Biological Opinion. The education program would include definition of “take” and specification, actions that must be avoided, procedures for handling tortoises found on roads, and identification of personnel authorized to handle or otherwise capture and relocate tortoises.

- Marking or telemetry of tortoises would not be allowed.

2. Minimize entrapment of tortoises in open trenches.

   - During tortoise active season, all open trenches with slopes steeper than 0.3 meter (1 foot) rise per 0.9 meter (3 feet) of length would be fenced off, covered, or constructed with escape ramps if they were not immediately backfilled.

   - Open trenches would be inspected for entrapped animals immediately prior to backfilling.

   - If a tortoise was discovered in a trench, all activities associated with the trench would cease until a qualified biologist had removed the tortoise.

3. Minimize predation on tortoises by ravens drawn to the project area.

   - DOE would implement a litter control program that would include the use of covered, raven-proof trash receptacles; disposal of edible trash in trash receptacles after each workday; and disposal of trash in a sanitary landfill. Materials placed in a landfill would be covered often enough to prevent ravens and other predators from feeding in the area.

4. Minimize destruction of tortoise habitat due to project activities

   - DOE would revegetate areas no longer required by the project in accordance with existing procedures and pursuant to site-specific rehabilitation plans prepared in accordance with the Biological Opinion.

5. Ensure compliance with reasonable and prudent measures, terms and conditions, reporting requirements, and reinitiation requirements in the Biological Opinion.

   - DOE personnel would have to acquire appropriate State permits from the Nevada Division of Wildlife prior to handling a desert tortoise, carcass, or egg.

   - DOE would designate a field representative (who could also serve as the environmental monitor), who would be responsible for overseeing compliance with protective stipulations and for coordinating compliance with the terms and conditions of the Biological Opinion, and who would have authority to halt construction equipment activities that could be in violation of the protective stipulations.

   - DOE would keep an up-to-date log of all actions related to the consultation, including acreage affected, habitat rehabilitation actions completed, number of desert tortoises taken and by what means (injured, killed, captured and displaced, or found in trenches or pits). The information would be provided to the U.S. Fish and Wildlife Service Las Vegas Office in the form of an annual report on February 28 of each year during which activities addressed by the Biological Opinion occurred.

9.2.4.2 General Biological Resources and Soils

Impacts to biological resources at the Yucca Mountain site could include habitat fragmentation, loss of individual members of different species, and encroachment of noxious weeds.

Potential soil impacts or concerns related to the proposed repository can be categorized as (1) increased soil erosion rates, (2) slow recovery rate of disturbed soils in the Yucca Mountain environment, and (3) introduction of contaminants. Erosion could result in the loss of the thin topsoil from the disturbed areas, which could affect long-term recovery, be a threat to structures in the region, and result in increased depositions downhill.

General Biological Resources and Soils Measures Under the Proposed Action

- Use the measures described in Section 9.2.2 to control erosion, dust, and particulate matter and therefore to lessen the consequences for biological resources and soils from repository construction, operation and monitoring, and closure.
- Use dust suppression measures such as application of water or environmentally sensitive methods to minimize wind and other erosion and aid recovery on disturbed areas.
- Conduct preconstruction surveys in floodplains to ensure that work would not affect important biological resources and to determine the reclamation potential of sites.
- Consider measures to relocate or avoid sensitive species in floodplains.
- If construction could threaten important biological resources in floodplains, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation.

General Biological Resources and Soils Measures Under Consideration

- Align and locate facilities, roadways, cleared areas, laydown areas, and similar construction activities to minimize fragmentation of habitat potentially affected by the proposed project.
- Mitigate potential soil erosion by minimizing areas of surface disturbance and using engineering practices to stabilize disturbed areas. These practices could include such measures as stormwater runoff control through the use of holding ponds, baffles, and other devices and the compacting of disturbed ground, relocated soil, or excavated material in places outside desert tortoise habitat.
- Mitigate the introduction of contaminants to soils, using methods similar to those described for surface-water impacts (see Section 9.2.3.1).
- To aid recovery, strip and stockpile topsoil from disturbed areas (excavated rock pile, etc.). When the disturbed areas are no longer needed, spread the topsoil over the areas and reseed the soil to improve the success of vegetation reestablishment and prevent encroachment of invasive species.
- Provide escape ramps from ponds and basins.

9.2.5 CULTURAL RESOURCES

Land clearing, excavation, and construction activities have the potential to disturb or cause the relocation of cultural artifacts. The operation of industrial facilities can degrade the value of traditional sites or uses. In addition, human activity in project areas causes concern that members of the workforce could affect cultural resource sites, especially those at buried locations or with artifacts.

Actions that DOE would take to mitigate adverse impacts to cultural resources at Yucca Mountain include those required by law or regulation and those that DOE determined the project would include to reduce such impacts. In some cases, precise mitigation measures cannot be identified due to the limited nature of the data (for example, construction activities could reveal previously unidentified sites). To address these cases, programmatic mitigation measures that comply with historic preservation laws and regulations are in place to ensure that DOE would implement appropriate measures following the identification and evaluation of important cultural resources.

The *Programmatic Agreement Between the United States Department of Energy and the Advisory Council on Historic Preservation for the Nuclear Waste Deep Geologic Repository Program, Yucca Mountain, Nevada* (DIRS 104558-DOE 1988, all) contains the requirements and general procedures for the mitigation of adverse effects at important archaeological and historic sites in the Yucca Mountain region during site characterization. DOE would work to review and update that agreement to establish requirements and procedures for mitigation of any adverse effects at important archaeological and historic sites during construction, operation and monitoring, and closure of the proposed repository in the event the repository was authorized.

The *Research Design and Data Recovery Plan for the Yucca Mountain Project* (DIRS 103196-DOE 1990, all) outlines more detailed approaches and procedures for implementing the mitigation of impacts to archaeological sites. Along with other topics, that document provides specific guidelines for determining the rationale, methods, analytical requirements, and logistics for archaeological mitigation measures at Yucca Mountain. In addition, the Department would consult with affected Native American tribes and organizations to ensure that repository activities avoided or minimized adverse impacts to resources or places that are important to American Indians.

Cultural Resources Measures Under the Proposed Action

- Ensure that onsite employees complete cultural resource sensitivity and protection training to reduce the potential for intentional or accidental harm to sites or artifacts. The training could include descriptions of the importance of different cultural resource types, procedures to follow if resources were encountered in the field, and employment-related and legal penalties for not following the requirements.

- Continue to use the Yucca Mountain Project Native American Interaction Program, which has been in existence since 1985, to promote a government-to-government relationship with Native American tribes and concentrate on the continued protection of important cultural resources. A considerable part of this effort could continue to be directed at protecting these resources and mitigating adverse effects to the fullest extent possible. Historically, as part of this program, members of Native American tribes have made recommendations to DOE about potential adverse effects, mitigation procedures that involve required consultation with tribal governments, and direct involvement of Native Americans in proposed project activities that could affect cultural resources or values (DIRS 102043-AIWS 1998, pp. 1-1, 2-3, and B-1 *et seq.*). Examples of suggested mitigations include incorporating the assistance of Native American people, continued protection of archaeological sites, funding Native American studies on impacts to natural resources and impacts from transportation (DIRS 102043-AIWS 1998, pp. 4-8 to 4-12).

- Conduct preconstruction surveys to ensure that work would not affect important archaeological resources and to determine the research potential of sites.

- If construction could threaten important archaeological resources, and modification or relocation of roads or rail lines would not be reasonable, develop additional mitigation measures.

9.2.6 OCCUPATIONAL HEALTH AND PUBLIC SAFETY

There would be a potential for repository workers to be exposed to radiation during the operation and monitoring and closure phases of repository activities or to be injured or killed as a result of hazards present in the industrial workplace (Chapter 4, Sections 4.1.7 and 4.1.8; Chapter 8, Section 8.2.7).

Erionite and cristobalite are hazardous materials that occur naturally in the Yucca Mountain subsurface. Erionite occurs in strata at varying depths below the planned level of the repository. DOE is mapping these strata as part of a general approach that emphasizes avoidance of erionite. If erionite was encountered during drilling, DOE would shut down the affected portion of its operation until it could put proper controls in place.

Cristobalite, which occurs generally in the subsurface rock structure, could be released during excavation operations or in fugitive dust from the excavated rock pile. There would be a potential for cristobalite to be an inhalation hazard to workers. Implementing specific health and safety plans to prevent worker exposure would minimize risks. Chapter 4, Section 4.1.7, discusses erionite and cristobalite.

After closure, there would be potential for human intrusion that could result in release of radioactive materials.

Occupational and Public Health and Safety Measures Under the Proposed Action

- Avoid erionite-bearing strata where practicable during repository construction and drift development.
- If drilling encountered erionite, close operations in potentially affected areas until proper controls were in place.
- Use high-efficiency particulate air filters or similar controls if drilling occurred in an area where there is potential for encountering erionite.
- Design repository construction procedures to reduce the risk of worker inhalation of cristobalite or erionite.
- Specify features of ventilation systems and other underground equipment to ensure the elimination of opportunities for occupational exposure to health and safety hazards.
- Use ventilation, planned transfer of cristobalite from work areas, and scrubbing of in-place dust to minimize exposure. Use monitoring devices and respirators as appropriate.
- Use ventilation to keep radon levels low in subsurface areas. Use higher ventilation rates and shorter air travel paths to reduce worker exposure to radon.
- Unload, handle, and package spent nuclear fuel and high-level radioactive waste remotely in hot cells or under water.
- Provide appropriate shielding during operations and during shipping and handling of packages when personnel would be present and could be exposed.
- Minimize to the extent practicable the amount of time workers would spend in the subsurface environment.
- Design task procedures to reduce the potential for accidents.
- Implement health and safety procedures and administrative controls to minimize risks to construction and operations workers.
- Design task procedures to reduce the potential for accidents that could lead to radioactivity releases in the workplace environment.

9.2.7 AESTHETICS

Construction, operation and monitoring, and closure of the proposed repository would require the lighting of certain areas of the repository at night. While the repository site is remote, and there are existing sources of nighttime light in the region, nighttime darkness is a valued component of the solitude experience sought by many individuals. Nighttime darkness enhances astronomy and stargazing activities and is one of the important scenic resources of Death Valley National Park.

Aesthetics Measures Under the Proposed Action

- Use exterior lighting only where needed to accomplish facility tasks.
- Limit the height of exterior lighting units, focusing more light on the ground surface and reducing the effects of night lighting on surrounding areas. This limitation would enable the use of reduced wattage output lamps, but could require the use of additional lighting units to obtain the same amount of ground coverage.
- Use shielded or directional lighting to limit the effects of the lighting to areas where it is needed.

Aesthetics Measures Under Consideration

- Orient ventilation system stacks and support structures and use re-contouring and natural vegetation to reduce facility visibility.

9.2.8 UTILITIES, ENERGY, AND MATERIALS

A monitored repository at Yucca Mountain would require a range of utility services, energy to power a variety of activities, and a number of diverse materials. DOE intends to promote efficiency in the use of utilities, energy, and materials.

Utility, Energy, and Materials Measures Under the Proposed Action

- Implement procedures and equipment that would minimize the use of utility services, energy, and materials.

9.2.9 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

As part of the repository design, DOE would institute a waste minimization program similar to the waste minimization and pollution prevention awareness plan successfully implemented during site characterization activities to minimize quantities of generated waste and to prevent pollution (DIRS 103203-YMP 1997, all). In addition, DOE would consider innovations to augment the existing program. The Department could keep the size of the Restricted (for radiological control) Area as small as possible, and it could implement programs to ensure that construction and operation activities used, as practicable, smaller quantities of products such as solvents and cleaners. The design of the proposed repository would incorporate pollution prevention measures and would provide cradle-to-grave waste management, as DOE provided during site characterization.

Waste and Hazardous Materials Measures Under the Proposed Action

- Recycle wastewater to reduce the amount of water needed for repository facilities and the amount of wastewater that could require disposal (DIRS 100248-CRWMS M&O 1997, p. 14).
- Use practical, state-of-the-art decontamination techniques such as pelletized solid carbon dioxide blasting that would reduce waste generation in comparison with other techniques (DIRS 100248-CRWMS M&O 1997, pp. 9-13 and 9-14).

- Institute preventive maintenance and inventory management programs to minimize waste from breakdowns and overstocking (DIRS 104508-CRWMS M&O 1999, p. 55).

- Whenever practicable, recycle nonradioactive materials such as paper, plastic, glass, nonferrous metals, steel, fluorescent bulbs, shipping containers, oils, and lubricants rather than dispose of them (DIRS 104508-CRWMS M&O 1999, pp. 62 and 70). Encourage the reuse of materials and the use of recycled materials.

- Avoid use of hazardous materials where feasible.

Waste and Hazardous Materials Measures Under Consideration

- When protective of the environment and cost effective, recycle dual-purpose canisters.

- Recycle solar panels if cost-effective and environmentally sound recycling options are available.

9.2.10 LONG-TERM REPOSITORY PERFORMANCE

DOE proposes a repository at Yucca Mountain to provide for permanent disposal of spent nuclear fuel and high-level radioactive waste. DOE's proposal includes a natural geologic setting that, with engineered repository and waste package barriers, would provide long-term isolation of spent nuclear fuel and high-level radioactive waste. In its design process, DOE is considering many features and approaches to contain and isolate the materials it proposes to place in the repository.

DOE's detailed study of the Yucca Mountain site and vicinity has resulted in the evaluation of three categories of potential measures: Barriers to limit the release and transport of radionuclides, measures to control heat and moisture in the confined environment of the repository, and measures to improve operational efficiency or safety. Each of these measures has the potential to complement the site's natural characteristics. These measures are conceptual in nature. The following sections summarize design features that could contribute to a reduction of the long-term potential for impacts from radionuclides isolated in a Yucca Mountain Repository. Long-term performance measures are discussed in more detail in Appendix E.

Long-Term Performance Measures Under the Proposed Action

DOE has designed an engineered barrier system that would complement the geologic and hydrologic properties of Yucca Mountain to isolate radionuclides in spent nuclear fuel and high-level radioactive waste from accessible portions of the environment. Design features that are part of the Proposed Action are presented below. The repository flexible design described in Chapter 2 of this EIS can be operated in a range of operating modes, from higher- to lower-temperature. Measures that are unique to only one operating mode are so noted.

- Use two-layer waste packages designed to remain intact for thousands of years (at a minimum), with layers that would fail only from different mechanisms and at different rates.

- Encapsulate spent nuclear fuel (normally in zirconium-alloy cladding) and immobilize high-level radioactive waste (normally in borosilicate glass or ceramic matrices) in the waste packages.

- Use nickel-chromium alloy (Alloy-22) emplacement pallets to hold waste packages off the floors of emplacement drifts.

- Use heat generated from the decay of radioactive material to heat the surrounding rock to drive water and gas away from the emplaced waste packages (higher-temperature operating mode).

- Use drip shields to provide a partial barrier to divert infiltrating water away from waste packages in an emplacement drift.

- Ground support options – Placing an engineered system into repository drifts to ensure drift stability before closure could both enhance safety during emplacement and potential retrieval and improve long-term repository performance by reducing or delaying damage to canisters from rockfall (damaged areas are locations for enhanced corrosion even if the canister is not breached by the rockfall).

- Increase the spacing between waste packages or drifts, or reduce the size of waste packages and maintain spacing to potentially reduce uncertainties regarding elevated temperature of the host rock and reduce waste package material corrosion rates (lower-temperature operating mode).

- Waste package spacing and drift spacing – Emplacing waste packages nearly end-to-end [that is, with a 0.1-meter (0.3-foot)-gap] with no consideration of individual waste package characteristics would provide a more intense and uniform heat source along the length of emplacement, requiring an increase in emplacement drift spacing and, potentially, continuous ventilation of emplacement drifts, but also would keep emplacement drifts hot and dry for a longer period, decrease the amount of water that could contact waste packages, and reduce the number of emplacement drifts needed for waste emplacement (higher-temperature operating mode).

- Use preemplacement aging and blending of spent nuclear fuel and high-level radioactive waste to provide thermal performance benefits. Aging would reduce the total thermal energy that the repository must accommodate, and blending would reduce the variability in the distribution of the thermal energy in the repository drifts. Potential benefits would be improved rock stability and retardation of waste package degradation (lower-temperature operating mode).

- Continuous preclosure ventilation – Continuous ventilation in the emplacement drifts before repository closure would reduce rock wall and air temperatures and remove moisture to reduce corrosion rates and increase the stability of the ground support system.

- Timing of repository closure – Extending the period before final closure, together with a maintenance program to accommodate an extended long-term repository service life and ground support components designed and maintained for a service life of up to 300 years, would allow for reduction of waste package heat output after closure, extended monitoring before closure, and an extended retrieval period for the waste (lower-temperature operating mode).

Long-Term Performance Measures Under Consideration

The design features listed below are being considered, though some are not currently under active consideration. These features are organized by their design purpose, either to limit release and transport of radionuclides, control heat and moisture in the repository environment, or support operational considerations.

Barriers to Limit Release and Transport of Radionuclides. The most direct method to provide the long-term isolation of contaminants is to use structures and techniques that have the potential to inhibit directly the release of contaminants from waste packages or to reduce the likelihood of the transport of released contaminants from the repository. DOE is considering a range of barrier measures that could enhance resistance to corrosion, delay or reduce water transport, retard radionuclide movement and release rates, and reduce the potential for damage to canisters. The Department will continue to evaluate the potential benefits and consequences of these measures together with their compatibility with overall repository system design.

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- Ceramic coatings on the exterior of the waste package – Could increase waste package life and repository waste isolation performance by reducing corrosion of the waste package surface and delaying the release of radionuclides.

- Diffusive barrier under waste packages – Loose, dry, granular material placed in the space between each waste package and the bottom of the emplacement drift to form a restrictive barrier to seepage, potentially slowing fluid and radionuclide movement to the natural environment.

- Getter under waste package – Placing a fine-grained material [either phosphate rock (apatite) or iron oxide (hematite, geothite, etc.] with an affinity for sorption of radionuclides in the recess below waste packages prior to waste emplacement could improve long-term waste isolation through retardation of radionuclide movement from the repository drifts.

- Canistered assemblies and waste-specific disposal containers – Placing spent fuel assemblies in canisters at the Waste Handling Building before inserting them into waste packages could provide an additional barrier and further limit mobilization of radionuclides if the waste package was breached.

- Additives and fillers – Placing materials (for example, oxides of iron and aluminum) into waste packages (in addition to those normally required for the basket material) to fill the basket and waste form void spaces could improve both the long-term repository performance (by retarding of release of radionuclides to the groundwater) and the long-term *criticality control*.

Measures to Control Heat and Moisture in the Repository Environment. Long-term influence over heat and moisture in the repository environment could increase the ability of the waste packages to isolate waste. DOE has evaluated measures that have the potential to control temperature and humidity levels in the repository to reduce corrosion rates, increase structural and support system stability, and increase the capability to retain released radionuclides in the repository. The Department will continue to examine the potential for enhancements in repository performance offered by these measures, other consequences of implementing them, and their compatibility with overall repository system design. DOE is considering the items listed below:

- Tailored waste package spatial distribution – Tailoring spatial distribution of the waste packages within the repository block according to waste package heat production, or the tendency of radionuclides in different packages to travel, resulting in a more uniform temperature across the repository. This would improve the performance of waste packages by delaying and reducing contact of water and/or increasing sorption of released radionuclides by zeolites in the unsaturated zone, thereby potentially improving repository waste isolation performance.

- Continuous postclosure ventilation design – Continuous ventilation of the emplacement drifts during the postclosure period could increase removal of moisture from air around the waste packages for a period of time (though moisture would eventually reestablish itself), and it could improve performance by retarding waste package corrosion.

- Drift diameter – A smaller diameter drift would be more stable (less rockfall potential), could reduce seepage into the drifts, and could reduce the need for ground support systems, while a larger diameter drift would allow for other modes of emplacement, such as horizontal or vertical borehole emplacement.

- *Near-field* rock treatment during construction – Filling cracks in a portion of the rock above each emplacement drift with grout to reduce or retard water seepage into the drifts after closure of the repository.

- Surface modification (alluvium) – Covering the surface of Yucca Mountain above the repository footprint with alluvium (soil) could decrease the net infiltration of precipitation water into the repository.

- Surface modification (drainage) – Removing the thin alluvium layer over the footprint of the repository would promote rapid runoff of surface water, potentially reducing infiltration from the top and improving long-term isolation of the waste.

Repository Designs to Support Operational Considerations. Including elements in the design that would enhance the repository's operational capabilities could improve access to waste packages after their emplacement, increase access for conducting performance confirmation, inspection, and maintenance activities, ease any effort to augment the repository system with later-developed materials or processes, and facilitate retrieval of waste packages if retrieval became necessary. DOE is considering measures that could provide additional shielding for personnel, increase usable space in drifts, increase opportunities for monitoring, and reduce the potential for moisture to contact waste packages. The Department will continue to assess the potential for design modifications to assist operational activities within the context of overall repository system design. DOE is considering the following potential design modification measures:

- Rod consolidation – Rod consolidation would involve bringing fuel rods into close contact with one another, allowing the capacity of waste packages to be increased and/or the size of waste packages to be reduced, potentially reducing the size or number of waste packages and, if consolidation were accomplished at the reactor sites, possibly reducing waste transportation shipments.

- Waste package self shielding – Adding a shielding material on the outside of waste packages would reduce the radiation in the drifts to levels such that personnel access would be possible.

- Repository horizon – A two-level repository would increase repository capacity without moving out of the characterized area. It would increase thermal load to reduce the amount of water that could come in contact with waste packages; add flexibility in emplacing waste packages on the lower level, which could be shielded from moisture infiltration by the upper level; and potentially facilitate retrieval due to the ability to operate two independent retrieval operations at the same time.

9.3 Transportation

This section discusses mitigation measures DOE is required to implement, has determined to implement, or has identified for consideration, to reduce potential impacts from the national transportation of spent nuclear fuel and high-level radioactive waste. These measures address impacts from the possible construction of a branch rail line or an intermodal transfer station in Nevada; construction of other transportation routes; upgrading of existing Nevada highways to accommodate heavy-haul vehicles; transportation of spent nuclear fuel and high-level radioactive waste from existing storage sites to the proposed repository; and fabrication of casks and canisters.

9.3.1 LAND USE

Mitigation measures could address three types of potential land-use impacts resulting from the construction and operation of a rail line or an intermodal transfer station: (1) impacts to publicly used lands such as grazing allotments, (2) direct and indirect land loss, and (3) displacement of capital improvements. Mitigation would not necessarily be associated with the potential selection of a route for heavy-haul trucks, which would follow existing rights-of-way and would require little additional land disturbance.

Land Use Measures Under the Proposed Action

- Ensure that construction activities were consistent with best management practices, by:
  - Ensuring that the location selection and final route alignment for a branch rail line or location selection for an intermodal transfer station, in consultation with parties controlling the surrounding lands, consider (1) the minimum impacts to private lands, capital improvements, floodplains or wetlands, areas containing cultural resources, or other environmentally sensitive areas, and (2) indirect loss of land or loss of use of land (the division of property or limitation of access) such as the use of grazing allotments.
  - Minimizing the size and number of easements.
  - During the rail construction phase, locating construction camps and staging areas along the rail line in consultation with parties controlling the surrounding lands.
  - Reclaiming disturbed areas outside the permanent right-of-way as soon as practicable after completion of construction.

Land Use Measures Under Consideration

- For grazed lands (lands grazed on by cattle), provide access across routes via underpasses, revegetate disturbed land, and aid in water provision (if access to water sources by herds is impeded).
- Coordinate DOE transportation schedules with U.S. Air Force training schedules to ensure that transportation of spent nuclear fuel and high-level radioactive waste through Air Force-controlled lands to a Yucca Mountain Repository would not result in safety-related restrictions being imposed on Air Force training activities.
- Implement additional rail realignments where feasible to avoid safety-imposed restrictions on U.S. Air Force use of lands the Air Force controls and uses for training purposes.
- If DOE selected the Bonnie Claire Alternate to the Caliente or Carlin rail corridor as part of its transportation route to Yucca Mountain, evaluate the potential for realignment of this alternate to reduce or eliminate the taking of land from the Timbisha Shoshone Trust Lands.
- Initiate no construction that would cross any presently designated wilderness study area unless that study area had been released from interim status by the State Director of the Bureau of Land Management as nonsuitable for wilderness or Congress has acted to remove the Wilderness Study Area designation.

9.3.2 AIR QUALITY

If DOE selected the Valley Modified rail corridor, mitigation measures could be needed to reduce fugitive dust emissions from rail line construction and carbon monoxide emissions from operations in the Las Vegas Valley nonattainment area. As described in Chapter 6, Section 6.3.2.2.5, fugitive dust emissions during the construction phase could be above the General Conformity Rule minimal levels for particulates. Vehicles used to transport workers and trains used to transport materials would generate criteria pollutants. States could place requirements for control of emissions of volatile organic compounds and nitrous oxide on facilities that manufacture containers and casks.

Air Quality Measures Under Consideration

- Employ two construction crews at half pace from opposite ends if the Valley Modified rail line was selected. Because only approximately 50 percent of the corridor length is in the Las Vegas Valley air basin, emission rates would be reduced to levels at or below General Conformity thresholds.

- Use buses to transport workers, reducing nitrogen oxide and hydrocarbon emissions.

- Reduce fugitive dust emissions using standard dust control measures routinely applied during construction projects including, for example, routine watering of unpaved surfaces; wet suppression for material storage, handling, and transfer operations; and wind fences to control windblown dust. The efficiency of these controls tends to vary depending on site characteristics, but it ranges from a 60- to 80-percent reduction in fugitive dust emissions (DIRS 103676-Cowherd, Muleski, and Kinsey 1988, p. 5-22).

- Reduce maximum fugitive dust concentrations with working controls such as scheduling construction operations to minimize concurrent generation by activities that were near each other (for example, conducting adjacent clearing and grading activities at different times).

9.3.3 HYDROLOGY

This section describes potential mitigation actions for both surface water and groundwater.

9.3.3.1 Surface Water

Three categories of potential impacts to surface water from the construction and operation of a Nevada transportation route are (1) the introduction of contaminants, (2) the alteration of drainage patterns or runoff rates, and (3) flood hazards. The spread of contamination by surface water could result in adverse impacts to plants and animals or to human health in the immediate area. It could also result in the recharge of contaminated water to groundwater. DOE's intent is to respond rapidly to such spills with appropriate cleanup actions.

Surface-Water Measures Under the Proposed Action

- Minimize disturbance of surface areas and vegetation, thereby minimizing changes in surface-water flow and soil porosity that would change infiltration and runoff rates.

- Mitigate flood hazards by designing facilities to withstand or accommodate a 100-year flood.

- Minimize the potential for contamination spread or other physical impacts to surface water by avoiding spills in unconfined areas and areas subject to flash floods, where practicable, and by locating the alignment of a branch rail line or heavy-haul road to avoid floodplains and surface waters, including wetlands, springs, and riparian areas, when possible, and to minimize any potential impacts to these features.

- Maintain natural contours to the maximum extent feasible, stabilize slopes, and avoid unnecessary offroad vehicle travel to minimize erosion.

- Minimize physical changes to drainage channels by building bridges or culverts where roadways would intersect areas of intermittent water flow. Use erosion control features such as proper placement of pipe, revegetation, and use of erosion control at these intersections where practicable to enhance the effectiveness of the bridges or culverts.

- Use physical controls such as secondary containment for fuel storage tanks to reduce the potential for releases to mingle with stormwater runoff.

- In and near floodplains, follow reclamation guidelines (DIRS 102188-YMP 1995, all) for site clearance, topsoil salvage, erosion and runoff control, recontouring, revegetation, siting of roads, construction practices, and site maintenance.

- Implement best management practices including training employees in the handling, storage, distribution, and use of hazardous materials to provide practical prevention and control of potential contamination sources.

- Conduct fueling operations and store hazardous materials and other chemicals in bermed areas away from floodplains to decrease the probability of an inadvertent spill reaching the floodplains.

- Provide rapid response cleanup and remediation capability, techniques, procedures, and training for potential spills.

Surface-Water Measures Under Consideration

- Designate bermed or contained sites outside areas subject to flash flooding for fueling and chemical handling to minimize the potential for contamination spreading if spills occurred.

9.3.3.2 Groundwater

Potential transportation-related impacts to groundwater would be most likely to occur from construction activities associated with a potential Nevada transportation route and could include introduction of contaminants and alteration of infiltration and runoff rates that could change the rate of recharge to the aquifer. Design and operational actions to reduce impacts would be identical to those described above for surface-water impacts.

Groundwater Measures Under the Proposed Action

- Implement best management practices, such as training employees in the handling, storage, distribution, and use of hazardous materials, to provide practical prevention and control of potential contamination sources.

- Minimize surface disturbance, thereby minimizing changes in surface-water flow and soil porosity that could change infiltration and runoff rates.

Groundwater Measures Under Consideration

- Place construction wells only in undesignated basins. (A Designated Groundwater Basin is one in which the quantity of appropriated water approaches or exceeds the perennial yield as *determined* by the Nevada State Engineer.)

- Employ water-use minimization and recycling techniques to reduce water consumption.

9.3.4 BIOLOGICAL RESOURCES AND SOILS

9.3.4.1 Desert Tortoise

The desert tortoise is a Federally protected species that resides at or along the candidate rail corridors, intermodal transfer station locations, and routes for legal-weight and heavy-haul trucks in Nevada (see Chapter 6, Sections 6.3.1, 6.3.2.1, and 6.3.3.1). Activities that could cause impacts to desert tortoises include site clearing, vehicle traffic, pond management, and taking of habitat.

DOE has been conducting site characterization activities in accordance with Fish and Wildlife Service biological opinions on the potential for impacts to desert tortoises (DIRS 104618-Buchanan 1997, pages 1 and 2). During these activities, five desert tortoises are known to have been killed by site characterization activities, all by vehicle traffic. A recent report (DIRS 103194-CRWMS M&O 1998, page 9) indicates that 27 of 28 individual tortoise relocations were successful and that two nest relocations were also successful. The one unsuccessful relocation involved a tortoise that returned to the area of disturbance and became one of the five killed by traffic.

If the proposed project proceeded, the U.S. Fish and Wildlife Service would establish measures, terms, and conditions for transportation activities that DOE would have to observe to protect the desert tortoise. DOE would implement terms and conditions established in any future biological opinions regarding the effects of repository-related transportation activities on the desert tortoise. As discussed in Chapter 6, areas that would be affected by transportation activities are at the extreme northern edge of the range of the desert tortoise, and the population of tortoises in these areas is low in relation to other portions of its range. No part of any of the candidate transportation routes has been declared critical habitat for the desert tortoise.

The final biological opinion on site characterization (DIRS 104618-Buchanan 1997, pp. 19 to 25) identified the following actions as requirements that DOE would need to implement to minimize impacts on desert tortoises. The U.S. Fish and Wildlife Service could establish similar conditions as prerequisites for transportation activities associated with the proposed project.

- Alignment and final siting of facilities, construction roadways, cleared areas, laydown areas, and similar elements of construction activity could avoid sensitive areas, lessen the likelihood of entrapment of tortoises, and minimize the fragmentation of known desert tortoise habitat.

- Measures to control erosion, dust, and particulate matter would lessen consequences of repository construction, operation and monitoring, and closure for desert tortoises. Similarly, approaches to minimize soil compaction and crushing of vegetation would lessen consequences for desert tortoises.

- Clearance surveys for desert tortoises before vegetation removal or soil disturbances of more than about 2 hectares (5 acres).

- Removal of tortoises or tortoise eggs found in areas to be disturbed, and tortoises in immediate danger along roads or near ongoing activities to safe nearby locations, with project activity ceasing until removal occurred.

- Prohibitions against driving vehicles off existing roads in nonemergency situations unless authorized. All workers at Yucca Mountain would participate in a required tortoise education program.

- A litter-control program that would include the use of covered, raven-proof trash receptacles, disposal of edible trash in trash receptacles following the end of each workday, and disposal of trash in a designated sanitary landfill.

- Revegetation of project areas no longer required.

- Construction and maintenance of tortoise-proof fencing to lessen the potential for endangerment to desert tortoises from project-related activities.

- Placement of escape ramps in trenches and inspection of trenches before filling.

Desert Tortoise Measures Under the Proposed Action

If a consultation process resulted from a determination that construction or operation of a transportation corridor associated with the proposed repository could affect threatened or endangered species or their habitat, DOE will adopt all reasonable and prudent measures to protect the desert tortoise or other species that could be stated in future biological opinions on transportation corridors.

The following text discusses potential transportation-related measures DOE has identified for the protection of the desert tortoise based on determinations the U.S. Fish and Wildlife Service made for site characterization.

- Align and locate facilities, roadways, and cleared areas and place appropriate signs to lessen the likelihood of trapping tortoises and to minimize habitat fragmentation.
- Minimize soil compaction and vegetation crushing.
- Move desert tortoises or desert tortoise eggs from areas to be disturbed, from roadways, and from proximity to ongoing activities to safe nearby locations; stop project activity until completion of these actions.
- Require authorization for nonemergency offroad vehicle travel.
- Ensure that all workers on the Yucca Mountain Project participate in a tortoise education program.
- Establish a litter-control program that would include the use of covered, raven-proof trash receptacles, disposal of edible trash in trash receptacles at the end of each workday, and disposal of trash in a designated sanitary landfill located away from desert tortoise habitat in order to avoid attracting potential predators.
- Revegetate project areas no longer required for the Proposed Action.
- Post road signs to remind drivers of the presence of desert tortoises and other animals, and enforce speed limits.
- Construct and maintain tortoise-proof fencing around actively used construction and operation sites to lessen the potential for danger from project-related activities.
- Provide escape ramps from trenches; inspect trenches before filling them.

9.3.4.2 General Biological Resources and Soils

Certain herds of migratory animals could be substantially affected if they were prevented from moving between ranges used at different times of the year. Some of the transportation routes under consideration cross game management areas and wild horse and wild burro management areas. Some routes cross areas traversed by herds of antelope, mule deer, elk, and mountain sheep. Fencing would not be likely to affect the movement of mule deer and elk. Fencing could impede the movements of antelope, mountain sheep, wild horses, and wild burros, effectively dividing management areas for these species.

General Biological Resources and Soils Measures Under the Proposed Action

- Use the measures described in Section 9.2.2 to control erosion, dust, and particulate matter and therefore to lessen the consequences for biological resources and soils from transportation activities.

- Use dust suppression measures on disturbed areas to minimize erosion and aid recovery by reducing wind erosion and supporting compaction.

- Conduct preconstruction surveys in floodplains to ensure that work would not affect important biological resources and to determine the reclamation potential of sites.

- Consider measures to relocate sensitive species in floodplains.

- If construction could threaten important biological resources in floodplains, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation.

General Biological Resources and Soils Measures Under Consideration

- Mitigate the introduction of contaminants to soils, using methods similar to those described for surface-water impacts (see Section 9.3.3.1).

- Conduct surveys of areas along the transportation corridor selected for construction to locate areas that are potential habitats for sensitive or State-protected species before the beginning of construction activities. Avoid springs, wetlands, waters of the United States, and riparian areas where practicable.

- Reduce habitat fragmentation and barriers to animal movement by considering the needs and movement patterns of mobile species (for example, wild horses) in the design and construction of rail lines, routes, and fencing. Seek input from wildlife agencies and organizations.

- If the construction and operation of a transportation route in Nevada could not avoid springs and wetlands, minimize the amount of disturbance (to the maximum extent possible) by carefully timing construction activities; minimizing corridor widths; locating laydown, excavated rock pile, and fueling areas away from sensitive areas where practicable; and conducting any wetlands replacement activities in accordance with plans approved by the U.S. Army Corps of Engineers.

- Align and locate facilities, roadways, cleared areas, laydown areas, and similar construction activities to minimize fragmentation of habitat potentially affected by the proposed project.

- Mitigate potential soil erosion by minimizing areas of surface disturbance and using engineering practices to stabilize disturbed areas. These practices could include such measures as stormwater runoff control through the use of holding ponds, baffles, and other devices and the compacting of disturbed ground, relocated soil, or excavated material in places outside desert tortoise habitat.

- To aid recovery, strip and stockpile topsoil from disturbed areas. When the disturbed areas were no longer needed, spread the topsoil over the areas and reseed the soil using local seed sources to improve the success of vegetation reestablishment and prevent encroachment of non-native invasive species.

9.3.5 CULTURAL RESOURCES

Land clearing, excavation, and construction activities have the potential to disturb or cause the relocation of cultural artifacts. The operation of industrial facilities can degrade the value of traditional sites or uses. In addition, human activity in project areas causes concern that members of the workforce could affect cultural resource sites, especially those at buried locations or with artifacts.

Actions that DOE would take to mitigate adverse impacts to cultural resources along transportation routes include those required by law or regulation and those built into the project to reduce such impacts. In some cases, DOE cannot identify precise mitigation measures due to the limited nature of the data (for example, construction activities could reveal previously unidentified sites). To address these cases, DOE has programmatic mitigation measures that comply with historic preservation laws and regulations in place to ensure that it would implement appropriate actions after the identification and evaluation of important cultural resources.

Cultural Resources Measures Under the Proposed Action

- Ensure that onsite employees complete cultural resource sensitivity and protection training to reduce the potential for intentional or accidental harm to sites or artifacts. The training could include descriptions of the importance of different cultural resource types, procedures to follow if resources were encountered in the field, and employment-related and legal penalties for not following the requirements.

- Continue to use the Yucca Mountain Project Native American Interaction Program, which has been in existence since 1985, to promote a government-to-government relationship with Native American tribes and concentrate on the continued protection of important cultural resources. A considerable part of this effort could continue to be directed at protecting these resources and mitigating adverse effects to the fullest extent possible. Historically, as part of this program, members of Native American tribes have made recommendations to DOE about potential adverse effects, mitigation procedures that involve required consultation with tribal governments, and direct involvement of Native Americans in proposed project activities that could affect cultural resources or values (DIRS 102043-AIWS 1998, p. 2-19). AIWS (DIRS 102043-1998, p. 4-1) suggested mitigations such as setting aside important cultural and ceremonial areas, and assisting in revegetation and reclamation activities.

- Conduct preconstruction surveys to ensure that work would not affect important archaeological resources and to determine the research potential of sites.

- If construction could threaten important archaeological resources, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation measures.

9.3.6 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

Over time, traffic accidents involving vehicles associated with the proposed repository would occur. The analysis indicated that fatalities and injuries from traffic accidents (nonradiological events) probably would constitute the largest impact to public health associated with the project. (See the Occupational and Public Safety and Health sections in Chapters 4 and 6.)

During the transportation of spent nuclear fuel and high-level radioactive waste, drivers and escort personnel would be routinely exposed to radiation and would receive radiological doses from this exposure. Workers and members of the public could receive doses from exposures resulting from an accident that released radionuclides.

Apart from impact findings and mitigations discussed in the EIS, Section 180(c) of the NWPA allows DOE to provide technical assistance and funds to states for training local government and Native American tribal public safety officials through whose jurisdictions DOE could plan to transport spent nuclear fuel or high-level radioactive waste. The training would cover procedures for safe routine transportation and for emergency response situations.

Occupational and Public Health and Safety Measures Under the Proposed Action

- Design task procedures to reduce the potential for accidents that could lead to radioactivity releases in the workplace environment.

Occupational and Public Health and Safety Measures Under Consideration

- Establish contract requirements to minimize worker exposure to ionizing radiation.
- Promote alternative transportation such as buses for workers to reduce automobile accidents.
- Implement a radiation protection plan for drivers and escort personnel.
- Implement accident reduction measures such as the Commercial Vehicle Safety Alliance procedures.

9.3.7 NOISE AND VIBRATION

Noise and vibration impacts could occur along a transportation corridor, depending on the scenario. Native Americans have expressed concern about noise associated with the transportation corridors and the movement of spent nuclear fuel and high-level radioactive waste to the proposed repository (DIRS 102043-AIWS 1998, p. 2-16). Impacts could result from the construction and operation of the facilities associated with transportation. There is concern that transportation activities could disrupt ceremonies that address Native American concerns for ecological health and the solitude needed for healing or prayer. Other communities could be subject to adverse noise and vibration levels, depending on the selected route and the potential to reduce such consequences. DOE expects the potential for adverse impacts from noise and vibration to be low.

Noise and Vibration Control Measures Under Consideration

- Avoid areas with sensitive receptors.
- Avoid Native American ceremonial sites.
- Consider noise and vibration intensity, time and distance, and noise canceling or interference factors when planning construction activities and facilities.
- If the transportation corridor passes through areas close to sensitive human receptors (schools, institutions, etc.), plan for noise abatement walls to reduce noise levels at specific locations.
- If the transportation corridor passes through areas close to structures and facilities that are sensitive to vibration (historic structures), plan for vibration abatement measures such as control of speed at specific locations.
- Install equipment that meets decibel limitations (see Chapter 6).
- Schedule vehicle travel through communities during daylight hours.
- Ensure that the receipt and transfer of material from railcars to heavy-haul trucks at an intermodal transfer station occurred during daylight hours.
- Impose speed limits on train or truck operations to reduce the intensity of noise and vibration in areas where there are sensitive receptors.

9.3.8 AESTHETICS

Construction along transportation routes and at facilities such as intermodal transfer stations and overnight stopping areas could reduce the quality of views in key locations. The operation of intermodal transfer stations and overnight stopping areas would require the lighting of these areas at night.

Aesthetics Measures Under the Proposed Action

- Remove or shape construction spoil piles to reflect existing contours. Keep the height of spoil piles that could not be removed or contoured to a minimum.

- Reclaim borrow areas using native vegetation.
- Plant native seedlings and other vegetation to help screen or reduce texture and color contrasts from key observation locations.
- Conduct an active misting and spraying program during construction to minimize the effects of fugitive dust.
- Reduce effects from outdoor night lighting used for intermodal transfer stations and overnight stopping areas by using measures similar to those discussed for lighting equipment above in Section 9.2.7.

9.3.9 MANAGEMENT OF WASTE AND HAZARDOUS MATERIALS

The manufacture of casks and containers could produce liquid and solid waste streams that would require disposal.

Waste and Hazardous Materials Measures Under the Proposed Action

- Design construction to include use of materials, such as depleted uranium, that could otherwise require disposal as wastes.
- Recycle lubricating and cutting oils.
- Recycle solid waste components where practicable.
- Employ ion exchange and filtration or similar methods to treat water used for ultrasonic weld testing for reuse in the manufacturing process.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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102188	YMP 1995	YMP (Yucca Mountain Site Characterization Project) 1995. *Reclamation Implementation Plan.* YMP/91-14, Rev. 1. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19970109.0256. In the Draft EIS, this reference was cited as DOE 1995g in Chapter 12.

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10

Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible or Irretrievable Commitment of Resources

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10. UNAVOIDABLE ADVERSE IMPACTS; SHORT-TERM USES AND LONG-TERM PRODUCTIVITY; AND IRREVERSIBLE OR IRRETRIEVABLE COMMITMENT OF RESOURCES

This chapter discusses adverse impacts that would remain after the application of mitigation measures (see Chapter 9). It analyzes the relationship between short-term uses of the human environment and the maintenance and enhancement of long-term productivity, and it identifies irreversible or irretrievable commitments of resources. The chapter presents information drawn from the analysis of the Proposed Action. It summarizes and consolidates information from the impact and mitigation analyses in Chapters 4, 5, 6, and 9, and provides references to earlier chapters for readers who require more detailed information.

The chapter discusses only resource areas for which preceding analyses have identified some potential for unavoidable adverse impacts. Nevertheless, the discussions in Sections 10.1, 10.2, and 10.3 reflect an examination of all of the resource areas analyzed in this EIS.

The construction, operation and monitoring, and eventual closure of the proposed Yucca Mountain Repository and the associated transportation of spent nuclear fuel and high-level radioactive waste would have the potential to produce some environmental impacts that the U.S. Department of Energy (DOE) could not mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources.

10.1 Unavoidable Adverse Impacts

This section summarizes potential impacts associated with the proposed repository and transportation actions that would be unavoidable and adverse and that would remain after DOE implemented mitigation measures, which are discussed in Chapter 9. Some aspects and activities discussed in Section 10.1 are analyzed from different perspectives in Sections 10.2 and 10.3.

10.1.1 YUCCA MOUNTAIN REPOSITORY

This section summarizes unavoidable adverse impacts associated with the construction, operation and monitoring, closure, and long-term performance of the proposed repository.

10.1.1.1 Land Use

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of land surrounding the Yucca Mountain site. DOE could obtain permanent control over the land only if Congress completed a land withdrawal action. A Congressional withdrawal would include lands already withdrawn for the Nevada Test Site and Nellis Air Force Range as well as lands under the control of the Bureau of Land Management and not currently withdrawn.

In general, the permanent withdrawal of land for the repository would prevent human use of the withdrawn lands for other purposes. Nevada Test Site activities would continue on a noninterference basis unless the Congressional land withdrawal specifically precluded them. DOE would remove mining and mineral claims from public use as they expired. Because the Yucca Mountain site has a low present resource value, is remote, and is partly withdrawn, the resultant impact would be small.

The disposal of spent nuclear fuel and high-level radioactive waste would permanently affect the availability of the subsurface area of the Yucca Mountain site and surface portions posted as off limits.

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The Chapter 4 land-use discussion includes the availability of the land and the consequences of withdrawal.

10.1.1.2 Air Quality

Construction, operation and monitoring, and closure of a repository at Yucca Mountain would produce small impacts to regional air quality. Radiological impacts could occur from the release of radionuclides. The principal radionuclides released from the subsurface would be naturally occurring radon-222 and its decay products in ventilation exhaust air. There are no applicable regulatory limits for radon releases from Yucca Mountain facilities. Other impacts would come from criteria pollutants and materials such as cristobalite and erionite. Exposures of maximally exposed individuals to radionuclides and criteria pollutants would be a small fraction of applicable regulatory limits. If offsite manufacturing occurred in nonattainment areas, the manufacturing processes could detract from the ability of local governments to meet air quality goals.

10.1.1.3 Hydrology

Construction activities would temporarily restrict and minimally alter natural surface-water drainage channels. Facilities and roadways would be designed to withstand at least a 100-year flood. Therefore, after construction was complete, only flow from infrequent more-intense floods would affect those facilities and roadways. Ground-disturbing activities and the surface facilities that DOE would build would alter surface-water infiltration and runoff rates in localized areas. Given the relatively small size of the affected land in comparison to the total drainage area, drainage channels and washes would experience little difference in impacts as a result of the disturbances. DOE estimates that overall consequences from the construction of roadways and facilities would be minimal.

The proposed repository construction and operation would unavoidably involve crossing washes designated as floodplains in the vicinity of Yucca Mountain, but effects on these washes would be small.

There would be withdrawals of groundwater during construction, operations and monitoring, and closure, but they would not exceed estimates of perennial yield. Chapter 4, Section 4.1.3, provides details on the effects of repository construction, operation and monitoring, and closure on hydrology.

Analysts estimate that the placement of drip shields would prevent dripping water from reaching the waste packages for more than 10,000 years (DIRS 154659-BSC 2001, Figure 4.2.5.1, p. 4F-39. Therefore, with the potential exception of a very small number of waste packages (0 to 3) that could fail due to manufacturing defects, there would be no breaches of waste packages before 10,000 years.

If water entered a waste package, it would have to penetrate the metal cladding of the spent nuclear fuel to reach the waste. For approximately 99 percent of the commercial spent nuclear fuel, the cladding is highly corrosion-resistant metal designed to withstand the extreme temperature and radiation environment in the core of an operating nuclear reactor. Current models indicate that it would take thousands of years to corrode cladding sufficiently to allow water to reach the waste and begin to dissolve the radionuclides.

During the thousands of years required for water to reach the waste, the radioactivity of most radionuclides would decay to virtually zero. Remaining radionuclides would have to dissolve in the water to pass from a waste package. Few of the remaining radionuclides could dissolve at a meaningful rate. Thus, only long-lived water-soluble radionuclides could get out of a waste package. Long-lived water-soluble radionuclides that migrated from the waste packages would then have to move down through about 300 meters (about 1,000 feet) of rock to the groundwater and then travel about 18 kilometers (11 miles) to reach a point where they could be taken up in a well and consumed or used to irrigate crops (see Chapter 5, Sections 5.3 and 5.4).

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As the long-lived water-soluble radionuclides began to move down through the rock, some would stick (or adsorb) to the minerals in the rock and be delayed in reaching the water table. After reaching the water table, radionuclides would disperse to some extent in the larger volume of groundwater beneath Yucca Mountain, and the concentrations would be diluted. Eventually, groundwater with varying concentrations of different radionuclides could reach locations in the hydrologic (groundwater) region of influence where the water could be consumed.

Of the approximately 200 different radioactive isotopes present in spent nuclear fuel and high-level radioactive waste, 26 are present in sufficient quantities and are sufficiently long-lived, soluble, mobile, and hazardous to contribute meaningfully to calculated radiation exposures.

10.1.1.4 Biological Resources and Soils

Unavoidable adverse impacts to biological resources would include the loss of small pieces of habitat totaling less than 6 square kilometers (2.5 square miles or 1,500 acres). The pieces that would be disturbed are habitat for terrestrial plant and animal species that are widespread throughout the region and typical of the Mojave and Great Basin Deserts. The death or displacement of individuals of some animal species as a result of site clearing and vehicle traffic would be unavoidable; however, changes in the regional population of any species would be undetectable.

No Federally endangered species are found on the site. The only Federally threatened species on the site is the desert tortoise (see Chapter 4, Section 4.1.4). Approximately 6 square kilometers (2.5 square miles or 1,500 acres) of desert tortoise habitat would be lost. This habitat is at the northern end of the range of the desert tortoise and is not designated critical habitat for the tortoise. The quantity of habitat that could be lost would be minimal in comparison to the range of the desert tortoise.

The U.S. Fish and Wildlife Service has issued a Biological Opinion (see Appendix O) stating reasonable and prudent measures and conditions that DOE would have to observe to protect the desert tortoise if the Proposed Action was implemented. DOE would adhere to all terms stated in the Biological Opinion, but, as the opinion acknowledges, individual tortoises could be killed inadvertently during site clearing, by vehicle traffic, or by predation from ravens. Preconstruction surveys, relocation of affected individuals, and adherence to conditions stated in the Biological Opinion would minimize, but not prevent, such deaths. Chapter 4, Section 4.1.4, discusses in detail the potential for loss of habitat or the deaths of individual members of this species. Chapter 9 (Sections 9.2.4.1 and 9.3.4.1) discusses mitigation measures to reduce potential impacts to the desert tortoise, including measures to locate facilities and roadways to avoid sensitive areas and measures to protect tortoises from construction impacts.

10.1.1.5 Cultural Resources

In the view of Native Americans, the implementation of the Proposed Action would further degrade the environmental setting. Even after closure and reclamation, the presence of the repository would, from the perspective of Native Americans, represent an irreversible impact to traditional lands.

NATIVE AMERICAN VIEW

A Native American view of facility and transportation route development, especially in remote areas such as Yucca Mountain and its surroundings, as expressed in the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, pages 2-20 and 3-1), is that development of such facilities and routes inherently degrades the entire environment. This view is based on the concept that the earth, its waters, the air, and the sky are a whole and have a sacred integrity in their natural form. Chapter 4, Section 4.1.13, of this EIS presents an environmental justice discussion of this Native American perspective.

Some unavoidable adverse impacts could occur to archaeological sites and other cultural resources, although no such sites or culturally important artifacts have been found at the site of the proposed repository. There could be a loss of archaeological information due to illicit artifact collection. In addition, excavation activities could cause a loss of archaeological information. Similarly, the location of a solar power generating facility on the repository site, could affect archaeological sites. Chapter 3, Section 3.1.6, discusses the program DOE has in place to address and mitigate cultural resource impacts and issues during site characterization. DOE anticipates this program would continue through repository closure.

10.1.1.6 Socioeconomics

The construction, operation and monitoring, and closure of a repository at Yucca Mountain would result in increased employment and population, which would place increased demands on housing and public services, including schools. Nonetheless, these demands would be small in comparison to total employment, population, real disposable income, gross regional product, and public expenditures in the region of influence.

10.1.1.7 Occupational and Public Health and Safety

There would be a potential for injuries to or fatalities of workers from facility construction, including accidents and inhalation of cristobalite and erionite. Cristobalite and erionite are naturally occurring hazardous materials in the rock of Yucca Mountain. Engineering controls and training and safety programs would reduce but not eliminate the potential for injuries or fatalities to workers.

Short-term impacts during the operation and monitoring phase would present a potential for injuries or fatalities to workers from industrial accidents and exposure to radioactive materials. Engineering controls and training and safety programs would reduce but not eliminate the potential. There would also be a potential for injuries and fatalities during closure. The occupational and public health and safety discussion in Chapter 4 (Sections 4.1.7 and 4.1.8) provides details on the potential for worker injuries and fatalities. The potential for injury or death to members of the public from exposure to radioactive materials or industrial activity would be extremely small.

While there would be a potential for radioactive contamination of groundwater during the 10,000-year analysis period from materials stored at the proposed repository, there would be only a small potential for such contamination to produce long-term adverse health impacts in the surrounding region during this period, even when the potential for changing climate and seismic events is considered. Potential long-term impacts to human health from the repository in the far future would be dominated by impacts from radioactive materials dissolved or suspended in water pathways. The dose to the reasonably maximally exposed individual would depend on the distance from the repository and the uses made of the land and waters.

At the compliance point defined in Chapter 5 [36 degrees, 40 minutes, 13.6661 seconds North latitude in the predominant direction of groundwater flow (40 CFR Part 197)], the highest 95th percentile annual dose to the reasonably maximally exposed individual for the 10,000-year analysis period would be 0.0001 millirem. The highest chance of a latent cancer fatality to this hypothetical individual would be 4 in 1 billion (see Chapter 5, Section 5.4.2.1). A latent cancer fatality is a cancer fatality that could occur after and as a result of exposure to radionuclides from the repository and that would be in addition to cancer fatalities occurring from all other causes.

Expected doses and consequences to the population from exposure to radionuclides transported by groundwater from the repository were forecast for the 10,000-year analysis period. The 95th-percentile population dose over the 10,000-year period could be 0.04 person-rem over an assumed 70-year lifetime.

The estimated 95th-percentile number of latent cancer fatalities in the population during any 70-year lifetime would be 0.00002. Over the 10,000-year analysis period, the estimated number of latent cancer fatalities would be 0.0003 (see Chapter 5, Section 5.4.2.1). These consequences would be small.

DOE estimates that most waste packages would remain intact longer than 10,000 years. Current model simulations forecast that some packages would last more than 1 million years. The highest 95th-percentile peak annual dose to a hypothetical reasonably maximally exposed individual could be 620 millirem approximately 410,000 years in the future. The highest mean peak annual dose rate to a reasonably maximally exposed individual at 18 kilometers (11 miles) could be 150 millirem per year approximately 480,000 years in the future (see Chapter 5, Section 5.4.2.1). In the unlikely event of an igneous disruption of the repository, the probability-weighted peak mean annual dose resulting to an individual would be approximately 0.1 millirem.

As determined by a bounding analysis (see Appendix I, Section I.6), there would also be a potential that chromium releases could produce estimated peak concentrations during the first 10,000 years of 0.01 milligram per liter at 18 kilometers (11 miles). This value is approximately one-tenth of the Maximum Contaminant Level Goal in drinking water.

10.1.1.8 Utilities, Energy, and Materials

The construction, operation and monitoring, and closure of a repository at Yucca Mountain would result in irreversible commitments of energy (mostly electricity and petroleum products) and materials (mostly cement, steel, and copper). These commitments would not be large enough to affect national or regional supplies.

10.1.2 NATIONAL TRANSPORTATION ACTIONS

10.1.2.1 Air Quality

To determine if pollutants of concern from national transportation by truck and rail would degrade air quality in nonattainment areas outside Nevada, DOE reviewed traffic volumes in nonattainment areas (see Chapter 6, Section 6.2). From this review DOE determined that the number of shipments to Yucca Mountain would be very small in relation to normal traffic volumes in the nonattainment areas studied, and that, therefore, impacts to air quality in these areas from repository-related shipments would be very small.

10.1.2.2 Occupational and Public Health and Safety

Certain adverse impacts to workers and the public from the transportation of spent nuclear fuel and high-level radioactive waste would be unavoidable. The loading and transportation of these materials would have the potential to affect workers and the public through industrial accidents, exposure to radiation and vehicle emissions, and through traffic accidents. This EIS evaluates two transportation scenarios—one in which DOE would transport the materials mostly by legal-weight truck and the other in which it would transport the materials mostly by rail. DOE estimates that the transportation of spent nuclear fuel and high-level radioactive waste nationally, including in Nevada, in the mostly legal-weight truck scenario could cause as many as 21 fatalities among workers and the public over the 24 years of the Proposed Action. These fatalities would include fatalities in industrial accidents, traffic fatalities, latent cancer fatalities caused by exposure to radiation, and health effect fatalities caused by exposure to vehicle emissions. DOE estimates that transportation mostly by rail could cause between 8 and 14 fatalities among workers and the public, including fatalities from upgrading and maintaining highways and constructing an intermodal transfer facility or constructing a branch rail line in Nevada as well as fatalities from operations over 24 years. These fatalities would also result from industrial accidents, vehicle crashes, radiation exposure, and exposure to vehicle emissions.

10.1.3 NEVADA TRANSPORTATION ACTIONS

This section summarizes unavoidable adverse impacts associated with the transportation of spent nuclear fuel and high-level radioactive waste and with the construction and operation of transportation facilities and routes in Nevada. Chapter 6 (Sections 6.1.2 and 6.3) provides more detailed discussions.

10.1.3.1 Land Use

Constructing and operating a new branch rail line would result in unavoidable changes to present land uses and control of the lands affected directly. The range of potentially affected uses includes grazing, wildlife habitat and management areas, mining, wilderness, Native American tribal uses, recreation, utility corridors, lands leased for oil and gas development, and military lands. Present uses of adjoining lands could also be affected to some extent. Each of the five corridors for a branch rail line encompasses a range of different land uses and surface features. If the choice was to construct a new branch rail line, the selection of a specific corridor would determine the land actually taken and the extent of impacts to land uses along that corridor. Land disturbed for a specific corridor implementing alternative could vary from 5.1 to 19.2 square kilometers (1,300 to 4,700 acres). Most land along the corridors under consideration is government administered or controlled. The Valley Modified Corridor crosses two Wilderness Study Areas. The Steiner Creek Alternate for the Carlin Corridor passes close to or encroaches on the Simpson Park Wilderness Study Area, depending on alignment. The Bonnie Claire Alternate for the Carlin and Caliente Corridors crosses lands of the Timbisha Shoshone Tribe near Scottys Junction, Nevada. The Caliente Corridor crosses a portion of the South Reveille Wilderness Study Area. The Caliente Corridor and the Caliente-Chalk Mountain Corridor pass through or encroach on the Weepa Springs Wilderness Study Area, depending on alignment.

Routes for heavy-haul or legal-weight trucks would follow existing highways and could require establishing and using access roads to obtain construction materials and additional land disturbance for road widening. Building and operating an intermodal transfer station would result in unavoidable changes of land use and ownership. The land for an intermodal transfer station could be public or private. Actual land uses lost would depend on the site and route selected. DOE expects that the total land disturbance for any implementing alternative for the construction of an intermodal transfer station and upgrades to existing highways could be as much as 3.5 square kilometers (about 860 acres). For heavy-haul truck routes originating at Caliente, an additional 0.04 square kilometer (10 acres) could be required for a midroute stop. A further 0.04 square kilometer could be required for the construction of a highway segment near Beatty, Nevada.

In some instances transportation facilities could remain in place to serve other purposes after DOE had ended use. Similarly, affected land could revert to other uses after the end of transportation activities and the removal of facilities.

10.1.3.2 Air Quality

The potential construction of the Valley Modified Alternate branch rail line or upgrades to roads to accommodate heavy-haul trucks in the Las Vegas Valley air basin, which is in nonattainment with Environmental Protection Agency standards for emissions of PM_{10} and carbon monoxide, could affect the ability of local governments to meet air quality goals.

The operation of a branch rail line or an intermodal transfer station and associated heavy-haul truck routes would lead to releases of pollutants, but these would be below thresholds of concern.

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Legal-weight truck shipments through the Las Vegas Valley air basin would also emit pollutants. However, the number of legal-weight truck shipments would be less than 1 percent of all truck traffic in the area and would not contribute discernibly to sources of air pollution.

10.1.3.3 Hydrology

The construction of a branch rail line or the upgrading of roads to accommodate heavy-haul transportation in Nevada would involve the unavoidable adverse impact of altering natural surface-water drainage patterns. Any of the Nevada transportation corridors would cross a number of natural drainage channels. Upgrade activities for a route to be used by heavy-haul trucks would involve the extension of existing drainage control structures as necessary to support the road upgrades. In this case, there would be minor changes to drainage channels already altered to some extent by the original road construction. The construction of a branch rail line would require alterations to many natural drainage areas along the line. Bridges and culverts would be used as necessary to cross streams, creeks, or, most predominantly, washes of any size. These structures would be built to accommodate a 100-year flow in the channels; the resulting drainage alteration would be confined to relatively small areas. Construction could alter small drainage channels or washes more because the railway design could call for the collection of some channels to a single culvert. At the end of the period during which DOE would transport spent nuclear fuel and high-level radioactive waste to the repository, the Department could remove facilities built for transportation and land recovery could begin, or it could use the facilities for other purposes. Appendix L contains a floodplain/wetlands assessment that presents a comparison of what is known about the floodplains, springs, and riparian areas along the five alternative rail routes and at the three alternative intermodal transfer station sites with their five associated heavy-haul truck routes.

In addition, the construction of a branch rail line or upgrades to a route for heavy-haul trucks would involve the withdrawal and use of water from groundwater resources. In many areas that a branch rail line would cross, other uses or commitments of groundwater resources approach or exceed the perennial yield of the underlying groundwater basins. The Nevada State Engineer has identified these areas as Designated Groundwater Basins, which the State watches for potential groundwater depletion. DOE would apply for State water appropriations for withdrawal of groundwater from any wells it developed to construct a branch rail line or would acquire water from appropriated sources and ship the water to its construction sites.

10.1.3.4 Biological Resources and Soils

Unavoidable adverse impacts to biological resources from transportation in Nevada could occur as a result of habitat loss and the deaths of small numbers of individuals of species along transportation routes. Habitat loss would be associated with the construction of either a new rail line or an intermodal transfer station and upgrades to existing highways. This loss would occur in widely distributed land cover types, and would include the loss of a small amount of desert tortoise habitat and the deaths of a small number of tortoises. The deaths of individual members of a species as a result of construction activities or from vehicle traffic would be unlikely to produce detectable changes in the regional population of a species.

Transportation route construction or upgrades would subject disturbed soils to increased erosion for at least some of the construction phase. The recovery of these disturbed areas to predisturbance conditions would occur with the passage of time. Transportation facilities such as a branch rail line could be used for nonrepository-related purposes, potentially extending their useful life beyond the period needed for the Proposed Action. The removal of transportation facilities after the end of their useful life would assist habitat recovery.

Disturbance of habitat could lend to intrusion of invasive species. These species would compete with native species and could become dominant in areas adjacent to the routes. In addition, they could increase the risk of fire in areas adjacent to the routes.

10.1.3.5 Cultural Resources

Some unavoidable impacts could occur to archaeological sites and other resources as a result of the construction of a rail line or the upgrade of a highway to heavy-haul capability. The potential for impacts to specific resources cannot be identified before final surveys and actual construction. An agreement now in effect between DOE and the Advisory Council on Historic Preservation for repository site characterization could serve as a model for an agreement to protect archaeological sites and other resources along transportation corridors. In addition, a number of statutes provide protective frameworks (see Chapter 11). Nevertheless, there would be a potential for grading and other construction activities to degrade, cause the removal of, or alter the setting of archaeological sites or other cultural resources. Although mitigated to some extent by worker education programs, there could be some loss of archaeological information due to the illicit collection of artifacts. In addition, excavation activities could cause loss of archaeological information.

10.1.3.6 Socioeconomics

The construction of a branch rail line in Nevada or of an intermodal transfer station and upgrades to associated highways for heavy-haul trucks would result in the irreversible use of economic resources. In addition, economic activity spawned by construction and subsequent operations would affect the availability and cost of resources used for other purposes in Nevada. Increased employment and population would place increased demands on housing and public services, including schools. Nonetheless, overall socioeconomic impacts in the region of influence would be small in comparison to total employment, population, real disposable income, Gross Regional Product, and public expenditures.

10.1.3.7 Occupational and Public Health and Safety

Certain adverse impacts to workers and the public from the construction and operation of the rail and heavy-haul implementing alternatives would be unavoidable. Table 10-1 presents potential health and safety impacts to workers and the public (fatalities) during construction and operations for each implementing alternative.

Table 10-1. Unavoidable adverse impacts from rail and heavy-haul truck implementing alternatives.[a]

	Construction (worker and public fatalities)	Operations (worker and public fatalities)
Rail		
Caliente	1.6	1.5
Carlin	1.4	1.6
Caliente-Chalk Mountain	1.0	1.4
Jean	0.89	1.3
Valley Modified	0.5	1.1
Heavy-haul truck[b]		
Caliente	1.8	4.5
Caliente/Chalk Mountain	0.74	3.8
Caliente/Las Vegas	1.3	4.3
Apex/Dry Lake	0.6	3.0
Sloan/Jean	0.6	3.1

a. Source: Chapter 6, Sections 6.3.2.2 and 6.3.3.2.
b. Includes intermodal transfer station impacts.

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The transportation of spent nuclear fuel and high-level radioactive waste would have the potential to affect workers and the public in Nevada through exposure to radiation and vehicle emissions and through traffic accidents. This EIS evaluates two transportation scenarios—one in which DOE would transport the materials mostly by legal-weight truck and the other in which it would transport the materials mostly by rail to Nevada and then to the repository by either heavy-haul truck or a branch rail line. DOE estimates that the transportation of spent nuclear fuel and high-level radioactive waste in the mostly legal-weight truck scenario could cause approximately 1.4 fatalities among workers and the public in Nevada as a result of exposure to radiation, vehicle emissions, and accidents over the course of 24 years. Over the same period, DOE estimates that transportation using a branch rail line in Nevada could cause up to 3.1 fatalities among workers and the public, while use of heavy-haul trucks in Nevada could result in up to 6.3 worker and public fatalities.

10.1.3.8 Aesthetics

The construction of a branch rail line in the Jean Corridor (Wilson Pass Option) would lead to a change to the aesthetic resource value of lands along the western slopes of the Spring Mountains, which the Bureau of Land Management classifies as a Class II visual resource. The construction of an intermodal transfer station near Caliente, Nevada, could affect the aesthetic value of lands in the entrance portion of the Kershaw-Ryan State Park until the station was removed.

10.1.3.9 Noise and Vibration

The long-term use of a branch rail line in any of the five rail corridors in Nevada would lead to an increase in ambient noise from periodically passing trains in areas of the State that are currently mostly uninhabited. This could affect solitude which the American Indian Writers Subgroup identified as essential for meditation and prayer. In addition, it could degrade the recreation values of the areas for individuals who seek primitive outdoor experiences. Noise from trains could be noticeable as new noise in residential areas near a potential branch rail line.

For Nevada transportation implementing alternatives that would use heavy-haul trucks, the noise from the trucks and the operation of an intermodal transfer station would be only slightly discernable above the noise of normal traffic and nearby industrial or railroad noise.

10.1.3.10 Utilities, Energy, and Materials

The construction of a branch rail line or upgrades to highways for use by heavy-haul trucks and construction of an intermodal transfer station would result in irreversible commitments of energy (mostly petroleum products) and materials (steel, concrete, and rock). These commitments would not be large enough to affect national or regional supplies.

10.1.3.11 Waste Management

The construction and operation of any of the 10 Nevada heavy-haul truck or rail implementing alternatives would generate small amounts of construction debris, sanitary solid waste, sanitary sewage, and hazardous waste. This waste would be managed by recycling, placement in permitted landfills, reuse or, in the case of sanitary sewage, onsite treatment and disposal. Waste would be managed in accordance with applicable requirements to minimize the possibility of adverse impacts to the environment. A small amount of low-level radioactive waste could be generated at an intermodal transfer station under the heavy-haul truck implementing alternative and would be disposed of in accordance with applicable regulations. The quantities of waste to be disposed of would not affect the availability of waste disposal resources for other users.

DOE would use excavated soil and rock from the construction of a branch rail line and the State of Nevada would use material from existing borrow areas and roadway excavations (highway upgrades) for fill to the extent feasible. However, some previously undisturbed areas could be covered with excavated soil and rock. To place and stabilize these materials, DOE would use approved practices that would minimize affected land areas and reduce potential impacts to biological resources and surface-water resources.

10.2 Relationship Between Short-Term Uses and Long-Term Productivity

The Proposed Action could require short-term uses of the environment that would affect long-term environmental productivity. This section describes possible consequences to long-term productivity from those short-term environmental uses.

The EIS analysis identified two distinct periods for the evaluation of the use of the environment by the Proposed Action:

- A period of 115 to 341 years for surface activities consisting of construction, operation and monitoring, and closure of the proposed repository. DOE activities during this period would include construction of facilities, receipt and emplacement of spent nuclear fuel and high-level radioactive waste, recovery of recyclable materials, ventilation of subsurface emplacement areas, decontamination, closure of surface and subsurface facilities, reclamation of land, and long-term monitoring. Sections 10.1.1.1 through 10.1.1.6 describe the unavoidable impacts that could occur during this period. This period would be the only time during which DOE would actively use the affected lands and the only time during which activities would involve the surface of the land used for the repository.

- The balance of a 10,000-year period would be for the evaluation of consequences from the disposal of spent nuclear fuel and high-level radioactive waste.

In general, transportation and disposal activities associated with the proposed repository would benefit long-term productivity by removing spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites around the country. In addition, removing these materials from existing sites would also free people and resources committed—now and in the future—to monitoring and safeguarding these materials for other potentially more productive activities. Removal could create conditions that would enable the initiation of other productive uses at the commercial and DOE sites. Finally, disposing of spent nuclear fuel and high-level radioactive waste in the proposed repository would provide a long-term global benefit by isolating the materials from concentrations of human population and human activity, thereby reducing the potential for sabotage.

10.2.1 YUCCA MOUNTAIN REPOSITORY

This section summarizes the relationship between short-term uses of land and resources and long-term land and resource productivity for the construction, operation and monitoring, closure, and long-term performance of the proposed repository. The terms "short-term" and "long-term" commonly used in National Environmental Policy Act analyses do not have a consistent duration in this section. For the analysis of impacts associated with repository activities, *short-term* refers to the time from the start of construction to the end of relevant surface and subsurface human activity, which DOE anticipates to range from 115 to 341 years. *Long-term* refers to the time between the end of relevant surface and subsurface human activity and the time when environmental resources have recovered from the potential for impacts and are again productive, or a maximum of 10,000 years. For transportation, *short-term* refers to the time of construction or actual transportation, as appropriate. *Long-term* refers to the time from the end of the short-term period to the time of environmental recovery. *Productivity* refers to the ability of an element of the environment to generate crops, provide habitat, or otherwise serve as a medium for the creation of value.

10.2.1.1 Land Use

From the start of construction through the 10,000-year period, the construction, operation and monitoring, and closure of the proposed repository would deny other users the use of the Yucca Mountain vicinity for other purposes. Chapter 4, Section 4.1.1, discusses the long-term uses of land. Conversely, a repository at Yucca Mountain would enable consideration of other uses for the sites where spent nuclear fuel and high-level radioactive waste are being stored and the land buffering those sites. Many present storage sites are in locations that would permit a wider range of alternative uses than does Yucca Mountain.

10.2.1.2 Hydrology

The proposed repository would be in a terminal basin that is hydrologically isolated and separated from other bodies of surface and subsurface water; that is, once water enters the basin it can leave only by evapotranspiration. As explained in Section 10.1.1.3, there would be a potential for materials disposed of at the proposed Yucca Mountain Repository to reach groundwater at some time between several thousand years and several hundred thousand years. If such contamination reached groundwater in the accessible environment, and if the groundwater contamination exceeded applicable regulatory requirements, there could be an attendant loss of productivity for the affected groundwater and for surface waters in the basin that the groundwater supplied. Conversely, the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain would free a wide range of major and minor water bodies throughout the United States from the potential threat of radioactive contamination from the materials at the present storage sites.

10.2.1.3 Biological Resources and Soils

Short-term uses that could cause impacts to biological resources and soils would be associated with the construction, operation and monitoring, and closure of the repository; those activities could lead to long-term productivity loss in disturbed areas. This loss would be limited to less than 6.0 square kilometers (1,500 acres) of widely distributed habitats adjacent to existing disturbed areas. Biological resources would be affected directly by land disturbances. The overall impact to populations of species would be limited because the area disturbed and the number of individual animals lost would be small in relation to the regional availability.

Long-term productivity loss for soils would be limited to areas affected by land disturbances. These areas would be revegetated after the completion of closure activities. Revegetation would be accomplished through the reclamation of disturbed sites using surface soils stockpiled during construction, reseeding, and similar activities that would enhance recovery. Chapter 4, Section 4.1.4, contains more detail on productivity losses and reclamation. The disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain would remove these materials from proximity to biota near the present storage sites across the United States.

10.2.1.4 Occupational and Public Health and Safety

A repository at Yucca Mountain would be likely to have a positive effect on the nationwide general occupational and public health because of the cessation of doses to workers at the present storage sites and because the spent nuclear fuel and high-level radioactive waste would be substantially more isolated from concentrations of people and from pathways to concentrations of people.

10.2.2 TRANSPORTATION ACTIONS

The construction of a rail line or an intermodal transfer station and improvements to existing highways, all short-term uses, could lead to a long-term loss of productivity in disturbed areas along the routes. In the context of transportation, *long-term* refers to the period of environmental recovery after the end of the construction period or the active use of a transportation route for repository purposes. A route could be used for repository purposes from 10 to approximately 30 years.

The land cover types along any route are widely distributed in the region. A loss of vegetation from a disturbed area along a route would have little effect on the regional productivity of plants and animals.

Productivity loss for soils would be limited to areas affected by land clearing and construction. These areas would not be available for revegetation and habitat for some time. Disturbed areas would recover, however, and eventually would return to predisturbance conditions, although the process of recovery would be slow in the arid environment. Chapter 6 contains more data on transportation.

The construction of a rail line, if the line were also used for nonrepository uses, could result in productivity benefits for Nevada by increasing transportation opportunities, lowering transportation costs, reducing accidents, and lowering nitrogen oxides, carbon monoxide, and other gaseous criteria pollutant emissions by diverting transportation from highway to rail.

The major long-term consequence of transporting spent nuclear fuel and high-level radioactive waste to the repository would be the permanent consolidation of these materials in an isolated location away from concentrations of people and without exposure pathways to concentrations of people.

10.3 Irreversible or Irretrievable Commitment of Resources

The Proposed Action would involve the irreversible or irretrievable commitment of land, energy, and materials. The commitment of a resource is irreversible if its primary or secondary impacts limit future options for the resource. An irretrievable commitment refers to the use or consumption of resources that are neither renewable nor recoverable for later use by future generations. Construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain would result in a permanent commitment of land, groundwater, surface, subsurface, mineral, biological, soil, and air resources; materials such as steel and concrete; and consume energy in forms such as gasoline, diesel fuel, and electricity. Water use would support construction, operation and monitoring, and closure actions, and options for using groundwater could become limited if there was contamination from radionuclides. There would be an irreversible and irretrievable commitment of associated natural resource services such as uses of land and habitat productivity.

10.3.1 YUCCA MOUNTAIN REPOSITORY

The construction, operation and monitoring, closure, and long-term performance of the Yucca Mountain Repository would result in the permanent commitment of the surface and subsurface of Yucca Mountain and the permanent withdrawal of lands from public use. Because of the remote location of Yucca Mountain, the lack of present uses of the land, the terminal and isolated nature of the water basin, and the limited amounts of materials and energy required for the repository in comparison to the supply capability of the regional and national economies, the irreversible and irretrievable commitments of resources for repository-related activities would be small.

Mitigation approaches that would involve the excavation of archaeological sites to prevent degradation by construction activities would destroy the contexts of those sites and reduce the finite number of such resources in the region. DOE expects that its activities at the proposed repository would affect no more than a minimal number of such sites. The Department would use state-of-the-art mitigation techniques on the Yucca Mountain Project.

Electric power, fossil fuels, and construction materials would be irreversibly committed to the project. Most of the steel used for the surface facilities would be recyclable and, therefore, not an irreversible or irretrievable commitment. Some copper and steel in the ramps and access mains to subsurface facilities would be recyclable, while some in the emplacement drifts would be irreversibly and irretrievably lost. Some steel, such as rebar, would be difficult to recycle. The quantity of resources consumed would be small in comparison to their national consumption or their availability to consumers in southern Nevada. These quantities are described in Chapter 4. To the extent that there is value in spent nuclear fuel or high-level radioactive waste, that value would be committed to the repository.

Aggregate would be crushed as required and mixed in concrete for the cast-in-place and precast concrete structures and liners that would be used in the repository. The amount of sand and aggregate could range from 1.2 million to 2.54 million metric tons (1.3 to 2.8 million tons). If Yucca Mountain tuff was used as the aggregate component of the subsurface concrete, the amount crushed and used as aggregate would be less than 15 percent of the total excavated from the drifts (see Chapter 4, Section 4.1.11).

Repository closure would make the energy content of uranium and plutonium in spent nuclear fuel unavailable for use by future generations.

10.3.2 TRANSPORTATION ACTIONS

The construction of a rail line or an intermodal transfer station would result in an irretrievable but not irreversible commitment of resources. Many resources could be retrieved at a later date through such actions as removing roadbeds, revegetating land, and recycling materials. Land uses would change along the selected transportation corridor during repository construction, operation and monitoring, and closure, thereby limiting or eliminating other land uses for that period. At the end of that period, however, land along the corridor could revert to public or private ownership.

Mitigation approaches involving the recovery of archaeological resources before construction activities degraded the sites would reduce the finite number of such resources in the Yucca Mountain region and destroy the context of sites. DOE would use state-of-the-art mitigation techniques during the construction of a rail corridor or an intermodal transfer station or the modification of roadways to accommodate heavy-haul trucks. Heavy-haul construction would be likely to generate only minimal impacts to cultural resources because construction would largely involve modifications to existing roads.

DOE would use about 500 to 700 million liters (132 to 185 million gallons) of fossil fuel from the nationwide supply system to transport spent nuclear fuel and high-level radioactive waste to the repository. The analysis in Chapter 6 (Sections 6.1.2.10, 6.3, 6.3.2.1, 6.3.2.2, 6.3.3.1, and 6.3.3.2), evaluates fuel use for the different transportation scenarios. The amount used would be a very small fraction of a percent of the Nation's supply over the period of fuel use.

The manufacture of casks and containers would require commitment of aluminum, chromium, copper, depleted uranium, lead, molybdenum, nickel, and steel. The required amounts of these materials, expressed as percentages of U.S. production, would be low with the exception of nickel, which would require approximately 8.2 percent of annual U.S. production.

REFERENCES

102043	AIWS 1998	AIWS (American Indian Writers Subgroup) 1998. *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement.* Las Vegas, Nevada: Consolidated Group of Tribes and Organizations. ACC: MOL.19980420.0041.
154659	BSC 2001	BSC (Bechtel SAIC Company) 2001. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.

11

Statutory and Other Applicable Requirements

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11. STATUTORY AND OTHER APPLICABLE REQUIREMENTS

The U.S. Department of Energy (DOE or the Department) has conducted site characterization activities in accordance with requirements of applicable laws and regulations and a range of permits and approvals that regulate the various aspects of the activities. The Department has successfully met environmental protection standards for its site characterization activities by developing a comprehensive approach to environmental compliance that ensures adherence to Federal and state requirements. It has implemented specific environmental compliance programs for pollution prevention, protection of cultural resources, and protection of threatened or endangered species. In its future actions involving Yucca Mountain, DOE will continue to comply with applicable Federal and state environmental requirements and with the conditions of the permits and approvals that might be required to conduct its activities, and will continue its involvement with tribal governments in accordance with Executive Orders, laws, and customs, and as based on relationships established by treaties.

This chapter identifies major requirements that could be applicable to the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. Section 11.1 lists statutory and regulatory provisions that set requirements potentially applicable to siting a monitored geologic repository. Section 11.2 summarizes statutes and regulations that set environmental protection requirements that could apply to a repository at Yucca Mountain. Section 11.3 contains a list of DOE Orders that could apply to activities related to the proposed repository. Section 11.4 contains a list of potentially applicable requirements compiled by the DOE Office of Civilian Radioactive Waste Management.

Table 11-1 lists potential new permits, licenses, and approvals that DOE could need for construction, operation, and closure of the Yucca Mountain Repository.

11.1 Statutes and Regulations Establishing or Affecting Authority To Propose, License, and Develop a Monitored Geologic Repository

Nuclear Waste Policy Act of 1982, as amended (42 U.S.C. 10101-10270)

The Nuclear Waste Policy Act, as amended in 1987 (NWPA), directs DOE to characterize and evaluate the suitability of only Yucca Mountain in southern Nevada as a potential site for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. After considering the suitability of the site and other information, the Secretary may then recommend approval of the site to the President. Further, the NWPA states that an environmental impact statement (EIS) must accompany any recommendation that the President approve the site for a repository. If the President recommends the Yucca Mountain Site to Congress and the designation takes effect, the NWPA provides that the Secretary of Energy must submit an application for construction authorization to the U.S. Nuclear Regulatory Commission not later than 90 days after the date on which the site designation is effective.

The NWPA directs the U.S. Environmental Protection Agency to promulgate generally applicable standards for protection of the environment from offsite releases from radioactive material in repositories. In addition, it requires the Nuclear Regulatory Commission to consider and approve or disapprove an application (if DOE submits one) for authorization to construct a repository for these materials based on Commission standards, which are to be consistent with the Environmental Protection Agency standards. In 1983, the Nuclear Regulatory Commission promulgated licensing requirements (10 CFR Part 60) that contain general criteria governing the issuance of a construction authorization and license for a geologic repository. These requirements would allow DOE to develop a repository for the receipt and disposal of spent nuclear fuel and high-level radioactive waste and would establish conditions under which DOE could receive and possess source, special nuclear, and byproduct material at a geologic repository. The

Table 11-1. Permits, licenses, and approvals needed for a monitored geologic repository.

Activity	Regulatory action	Statute or regulation	Agency(ies)
1. Disposal of spent nuclear fuel and high-level radioactive waste	Final public health and environmental protection standards	40 CFR[a] Part 197	Environmental Protection Agency
2. Repository construction, operation, and closure	Construction authorization, license to operate and monitor, and license for closure	10 CFR Part 63	Nuclear Regulatory Commission
3. Site suitability	Criteria and methodology for determining suitability of Yucca Mountain Site	10 CFR Part 963	Department of Energy
4. Repository construction, operation, and closure	Withdrawal of Land from Public Use	Future Congressional Bill needed to authorize withdrawal, 43 CFR Part 2300	Congress, Bureau of Land Management
5. Air emissions	Approvals for New Sources of Toxic Air Pollutants	40 CFR Parts 61 and 63	Environmental Protection Agency
		NAC[b] 445B.287 *et seq.*	Nevada Division of Environmental Protection
6. Air emissions	Air Quality Operating Permit	NAC 445B.287 *et seq.*	Nevada Division of Environmental Protection
7. Air emissions	National Emission Standards for Hazardous Air Pollutants Subpart H (Radionuclides)	40 CFR Part 61	Environmental Protection Agency
		10 CFR Part 20	Nuclear Regulatory Commission
	National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	Environmental Protection Agency
8. Certification of facilities	Certification of Air and Water Pollution Control Facilities	40 CFR Part 20	Environmental Protection Agency
9. Drinking water	Water System Operating Permit	NAC 445A.070 *et seq.*	Nevada Health Division
10. Effluents	Stormwater Discharge	40 CFR Part 122	Environmental Protection Agency
		NAC 445A.070 *et seq.*	Nevada Division of Water Planning
11. Effluents	National Pollutant Discharge Elimination System	40 CFR Part 122	Environmental Protection Agency
	State Water Pollution Control Permit	NAC Chapter 445A	Nevada Division of Water Planning, Nevada Division of Environmental Protection
12. Excavation; facility construction	Cultural Resource Review Clearance, Section 106 Agreement	36 CFR Part 800	Advisory Council on Historic Preservation, State Historic Preservation Officer
13. Excavation; facility construction	Permit to Proceed (Objects of Antiquity)	36 CFR Part 296 43 CFR Parts 3 and 7	Department of the Interior
14. Excavation; facility construction	Permit for Excavation or Removal of Archaeological Resources	16 U.S.C.[c] 470 *et seq.*	Department of the Interior, affected Native American Tribes
15. Facility construction	Free-Use Permit	43 CFR Part 3620	Bureau of Land Management, Forest Service
16. Facility construction	Permit for the discharge of dredged or fill materials to Waters of the United States	Clean Water Act, Section 404	U.S. Army Corps of Engineers
17. Transportation to Facility	Right-of-way reservations	43 CFR 2800	Bureau of Land Management
18. Facility construction and operation	Endangered Species Consultation	50 CFR 402.6	Fish and Wildlife Service
19. Materials storage	Hazardous Materials Storage Permit	NAC Chapters 459 and 477	Nevada State Fire Marshal

a. CFR = Code of Federal Regulations.
b. NAC = Nevada Administrative Code.
c. U.S.C. = United States Code.

requirements in 10 CFR Part 60 do not apply to any nonrepository activities licensed under other parts of Title 10 of the Code of Federal Regulations.

Congress originally passed the Nuclear Waste Policy Act in 1982. The 1982 legislation directed the Secretary of Energy to recommend potential sites to the President for possible characterization as geologic repositories, and it directed the President to select sites for characterization. The Nuclear Waste Policy Act also required the Secretary of Energy to issue general guidelines for use in recommending potential geologic repository sites for detailed site characterization. DOE issued those guidelines in 1984 (10 CFR Part 960) and applied them when it nominated five sites as suitable for characterization and recommended characterization of three of the sites.

DOE decided to include in the general guidelines a process for evaluating the data obtained from site characterization activities to be used in determining whether a site should be recommended for the development of a geologic repository. In 1996, DOE proposed to clarify and focus its 10 CFR Part 960 guidelines (to be codified at 10 CFR Part 963), but never issued those guidelines as final. In 1999, DOE proposed further revisions to the draft 10 CFR Part 963 guidelines (64 *FR* 67054). DOE has since finalized these changes and 10 CFR Part 963 has been promulgated (66 *FR* 57297). In the Site Recommendation, if any, DOE will consider these finalized guidelines.

Section 116(c) of the NWPA establishes a procedure by which DOE can consider and, if appropriate, address a broad array of considerations. The State of Nevada or an affected unit of local government can describe impacts that are likely to result from site characterization in a report and submit it to the Secretary of Energy. Section 116 of the NWPA allows DOE to consider these impacts as a basis for DOE providing technical or financial assistance. In contrast to the National Environmental Policy Act process, a Section 116(c) determination of impact assistance is not tied to an extensive body of past precedent or regulatory interpretations. DOE has broad discretion under Section 116(c) to consider impacts that the State of Nevada or an affected unit of local government might identify.

Energy Policy Act of 1992 (42 U.S.C. 10101 *et seq.*)

In the NWPA, Congress directed the Environmental Protection Agency to establish standards to protect the general environment from offsite releases from radioactive materials in repositories. The NWPA also directed the Nuclear Regulatory Commission to issue technical requirements and criteria that it will apply in approving or disapproving any applications regarding repositories. In 1992, Congress passed the Energy Policy Act, modifying the rulemaking authorities of the Environmental Protection Agency and the Nuclear Regulatory Commission with respect to the proposed repository at Yucca Mountain. Section 801(a) of the Energy Policy Act directed the Environmental Protection Agency to (1) retain the National Academy of Sciences to make findings and recommendations on reasonable public health and safety standards for Yucca Mountain, and (2) establish Yucca Mountain-specific standards based on and consistent with the National Academy of Science's findings and recommendations. Section 801(b) of the Energy Policy Act directs the Nuclear Regulatory Commission to modify its technical requirements and criteria for geologic repositories to be consistent with the site-specific Yucca Mountain standard (40 CFR Part 197) established by the Environmental Protection Agency. Section 801(c) of the Energy Policy Act requires that DOE continue its oversight of the Yucca Mountain site after closure to prevent: (1) Unreasonable risk of breaching the repository's barriers, and (2) Increasing the exposure of individual members of the public to radiation beyond allowable limits. The National Academy of Sciences issued its findings and recommendations in a 1995 report (DIRS 100018-National Research Council 1995, all).

Environmental Radiation Protection Standards for Yucca Mountain, Nevada (40 CFR Part 197)

In response to the Energy Policy Act of 1992, the Environmental Protection Agency has established Yucca Mountain-specific environmental standards for radioactive material stored at or disposed of in the Yucca Mountain site and for disposing of radioactive material in a Yucca Mountain repository (40 CFR

Part 197; see Table 11-1, item 1). The Environmental Protection Agency provisions set public health and environmental radiation protection standards.

As part of its evaluation of the potential for public health and environmental impacts, DOE measured the short-term and long-term performance of the repository system by comparing the volume and dispersion of analyzed releases against the 40 CFR Part 197 requirements as the Nuclear Regulatory Commission has adopted those requirements. Table 11-2 provides information on the 40 CFR Part 197 standards.

The disposal standards also include limits on radionuclides and types of radiation that releases from the repository could cause in groundwater during the 10,000-year period. The standards further require DOE to calculate the peak dose to the reasonably maximally exposed individual that would occur beyond 10,000 years but within the period of geologic stability and to include the results in this EIS.

Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain (10 CFR Part 63)

The U.S. Nuclear Regulatory Commission has established licensing regulations for disposal of spent nuclear fuel and high-level radioactive waste in the proposed geologic repository at Yucca Mountain, Nevada (10 CFR Part 63; see Table 11-1, item 2). The regulations establish site-specific technical requirements and criteria governing construction, operations and monitoring, closure, and long-term performance of the repository. If DOE submits appropriate applications, the Commission must use the requirements and criteria in 10 CFR Part 63 to determine whether to authorize the Department to construct a repository at Yucca Mountain, to license DOE to receive and possess spent nuclear fuel and high-level radioactive waste at such a repository, and to authorize DOE to close and decommission such a repository. To gain approval of a licensing application, the DOE repository design for Yucca Mountain must meet Nuclear Regulatory Commission requirements, including requirements for demonstrating compliance with the Environmental Protection Agency standards set forth at 40 CFR Part 197.

Title 10 CFR Part 63 includes the specification of overall performance objectives to protect the public health and safety during preclosure and postclosure phases of the repository. The technical criteria require that DOE demonstrate compliance with these overall performance objectives through an integrated safety analysis of preclosure operations, and through a performance assessment for long-term, postclosure performance. The criteria also address requirements for natural and engineered barriers, licensing procedures, public participation criteria, records and reporting, monitoring and testing programs, performance confirmation, quality assurance, personnel training and certification, and emergency planning. The criteria apply specifically and exclusively to the proposed repository at Yucca Mountain.

Yucca Mountain Site Suitability Guidelines (10 CFR Part 963)

The U.S. Department of Energy has set forth guidelines at 10 CFR Part 963 (see Table 11-1, item 3) to establish methods and criteria for determining the suitability of the Yucca Mountain site for the location and development of a geologic repository. The suitability determination is necessary to complete DOE's site characterization program activities required under section 113(b) of the Nuclear Waste Policy Act.

The guidelines focus on the criteria and methodology to be used for evaluating relevant geological and other related aspects of the Yucca Mountain site in assessing site suitability. The criteria and methodology are consistent with the latest scientific and analytical techniques and with the Nuclear Regulatory Commission's requirements set forth at 10 CFR Part 63 and the Environmental Protection Agency's standards established at 40 CFR Part 197. The guidelines consider the preclosure and postclosure periods, and are specific to Yucca Mountain.

Table 11-2. Title 40 CFR Part 197, Public Health and Environmental Protection Standards.

Component	Storage regulations	Disposal regulations
Individual Protection Standard[a]	150 microsieverts (15 millirem)[b]	150 microsieverts (15 millirem)[b]
Human Intrusion Standard	N/A[c]	150 microsieverts (15 millirem)[b]
Groundwater Protection Standard	N/A	• For combined radium-226 and radium-228, 5 picocuries per liter, including background radiation • For gross alpha activity (including radium-226 but excluding radon and uranium), 15 picocuries per liter, including background radiation • For combined beta- and photon-emitting radionuclides, 40 microsieverts (4 millirem) per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume, not including background radiation
Applicable period	Construction, operation and monitoring, closure until repository is sealed	10,000 years after repository is sealed
Standards apply to	All members of the public	Reasonably maximally exposed individual[d]
Location where compliance is assessed	Anywhere in the general environment	The location where projected concentrations would be highest and that is no closer to the repository than the edge of the controlled area
Geographic scope of standards	Everywhere other than the Yucca Mountain site, the Nellis Air Force Range, and the Nevada Test Site	Everywhere outside the surface and subsurface of the controlled area[e]

a. EIS Appendix F includes a primer on potential human health effects from exposure to radionuclides.
b. Annual committed effective dose equivalent, a combination of the dose an individual could absorb during a full year and any subsequent dose over a defined period of time from radionuclides remaining within the individual as a result of the dose absorbed during the year.
c. N/A = not applicable.
d. Represents a person who resides in the accessible environment above the highest concentration of radionuclides in the plume of contamination. The reasonably maximally exposed individual approach is based on providing a sufficient level of protection to this individual so that all other persons, who would be less exposed, would also be protected.
e. The location where projected concentrations would be highest, no closer to the repository than the edge of the controlled area. The controlled area would be 300 square kilometers (120 square miles) maximum surface and subsurface area that extends in the predominant direction of groundwater flow no farther south than 36 degrees, 40 minutes, 13.6661 seconds North latitude (the present southwest corner of the Nevada Test Site), and no more than 5 kilometers (3 miles) from the repository footprint in any other direction. The controlled area would be the area restricted long term for the repository as identified by passive institutional controls DOE would implement at closure.

National Environmental Policy Act of 1969, as Amended (42 U.S.C. 4321 *et seq.*)

DOE has prepared this EIS in accordance with the provisions of the National Environmental Policy Act as implemented by Council on Environmental Quality regulations (40 CFR Parts 1500 through 1508) and DOE National Environmental Policy Act regulations (10 CFR Part 1021), and in conformance with the NWPA.

Atomic Energy Act of 1954, as Amended (42 U.S.C. 2011 *et seq.*)

The Atomic Energy Act, as amended, provides fundamental jurisdictional authority to DOE and the Nuclear Regulatory Commission over governmental and commercial use of nuclear materials. The Atomic Energy Act ensures proper management, production, possession, and use of radioactive materials. In accordance with the Atomic Energy Act, DOE has established a system of requirements that it has issued as DOE Orders.

The Atomic Energy Act gives the Nuclear Regulatory Commission specific authority to regulate the possession, transfer, storage, and disposal of nuclear materials, as well as aspects of transportation packaging design requirements for radioactive materials, including testing for packaging certification. Commission regulations applicable to the transportation of radioactive materials (10 CFR Parts 71 and 73) require that shipping casks meet specified performance criteria under both normal transport and hypothetical accident conditions.

Under the Atomic Energy Act of 1954, as amended, the Environmental Protection Agency has the authority to develop generally applicable standards for protection of the general environment from radioactive material.

Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701 *et seq.*)

The Federal Land Policy and Management Act governs the use of Federal lands administered by the Bureau of Land Management, which is an agency of the U.S. Department of the Interior. Access to and use of public lands administered by the Bureau are primarily governed by the regulations regarding the establishment of rights-of-way (43 CFR Part 2800; see Table 11-1, item 17) and withdrawals of public domain land from public use (43 CFR Part 2300; see Table 11-1, item 4), as described below in this section.

Some implementing alternative branch rail lines, routes for heavy-haul trucks, and intermodal transfer station locations that could be involved in transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would cross or occupy land administered by the Bureau of Land Management and would require right-of-way reservations (see Table 11-1, item 17). DOE has obtained right-of-way reservations from the Bureau of Land Management and a concurrence from the U.S. Air Force for access to the Yucca Mountain vicinity for characterization activities.

To develop a monitored geologic repository at Yucca Mountain, DOE would need to obtain control of Bureau of Land Management, Air Force, and DOE lands in western Nevada. Land withdrawal is the method by which the Federal Government gives exclusive control of land it owns to a particular agency for a particular purpose. Nuclear Regulatory Commission licensing conditions for a repository include a requirement that DOE either own or have permanent control of lands for which it is seeking a repository license, and that lands used for a repository be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

The Federal Land Policy and Management Act, by which the Government accomplishes most Federal land withdrawals, contains a detailed procedure for application, review, and study by the Bureau of Land Management, and decisions by the Secretary of the Interior on withdrawal and on the terms and conditions of withdrawal. Withdrawals accomplished through the Federal Land Policy and Management Act remain valid for no more than 20 years and, therefore, do not appear to meet the permanency of control required by the Nuclear Regulatory Commission.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. In the absence of specific direction to another Federal agency the Bureau of Land Management would ordinarily administer details of a Congressional withdrawal, following the provisions of 43 CFR Part 2300.

Executive Order 11514, *National Environmental Policy Act, Protection and Enhancement of Environmental Quality*

Executive Order 11514 directs Federal agencies to monitor and control their activities continually to protect and enhance the quality of the environment. The Order also requires the development of procedures both to ensure the fullest practicable provision of timely public information and understanding of Federal plans and programs with potential environmental impacts, and to obtain the views of interested parties. DOE has promulgated regulations (10 CFR Part 1021, *National Environmental Policy Act Implementing Procedures*) and has issued a DOE Order (451.1A, *National Environmental Policy Act Compliance Program*) to ensure compliance with this Executive Order.

11.2 Statutes, Regulations, and Orders Regarding Environmental Protection Requirements

11.2.1 AIR QUALITY

Clean Air Act, as amended (42 U.S.C. 7401 *et seq.*)

The Clean Air Act is intended to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 of the Act requires Federal agencies such as DOE, with jurisdiction over any property or facility that might result in the discharge of air pollutants, to comply with "all Federal, state, interstate, and local requirements" related to the control and abatement of air pollution.

The Clean Air Act requires the Environmental Protection Agency to establish National Ambient Air Quality Standards to protect public health, with an adequate margin of safety, from any known or anticipated adverse effects of a regulated pollutant (42 U.S.C. 7409). It also requires the establishment of national standards of performance for new or modified stationary sources of atmospheric pollutants (42 U.S.C. 7411) and the evaluation of specific emission increases to prevent a significant deterioration in air quality (42 U.S.C. 7470). Air emission standards are established at 40 CFR Parts 50 through 99. The Clean Air Act specifically regulates emissions of hazardous air pollutants, including radionuclides, through the National Emission Standards for Hazardous Air Pollutants Program at 40 CFR Parts 61 and 63 (see Table 11-1, items 5 and 7).

Nevada Revised Statutes: Air Emission Controls, Chapter 445B

These statutes and regulations in the Nevada Administrative Code implement State and Federal Clean Air Act provisions, identify the requirements for permits for each air pollution source (unless it is specifically exempted), and identify ongoing monitoring requirements. In accordance with the Clean Air Act, DOE could have to obtain an Operating Permit from the Nevada Division of Environmental Protection for the control of gaseous, liquid, and particulate emissions associated with the construction and operation of a repository at Yucca Mountain (see Table 11-1, item 6). To ensure that its site characterization activities comply with applicable Clean Air Act and State provisions, DOE has obtained an operating permit for surface disturbances and point source emissions.

11.2.2 WATER QUALITY

Safe Drinking Water Act, as amended [42 U.S.C. 300(f) *et seq.*]

The primary objective of the Safe Drinking Water Act is to protect the quality of public water supplies, including any drinking water system at the proposed repository. This law grants the Environmental Protection Agency the authority to protect the quality of public drinking water supplies by establishing national primary drinking water regulations. In accordance with the Safe Drinking Water Act, the

Environmental Protection Agency has delegated authority for enforcement of drinking water standards to the states. Regulations (40 CFR Parts 123, 141, 145, 147, and 149) specify maximum contaminant levels, including those for radioactivity, in public water systems, which are generally defined as systems that serve at least 15 service connections or regularly serve at least 25 year-round residents.

In 1978, the Environmental Protection Agency approved the Nevada program for enforcing drinking water standards. The Nevada Health Division is responsible for enforcement of these standards. The proposed repository would include a drinking water system that obtained water from a source off the repository site, and DOE would operate the system in accordance with Nevada Health Division permitting requirements, if applicable (see Table 11-1, items 9, 10, 11, and 16).

Clean Water Act of 1977 (33 U.S.C. 1251 *et seq.*)

The purpose of the Clean Water Act, which amended the Federal Water Pollution Control Act, is to "restore and maintain the chemical, physical, and biological integrity of the Nation's water." The State of Nevada has been delegated the authority to implement and enforce most programs in the State under the Clean Water Act; exceptions include those addressed by Section 404, which is administered by the U.S. Army Corps of Engineers, as described below in this section.

The Clean Water Act prohibits the "discharge of toxic pollutants in toxic amounts" to navigable waters of the United States. Section 313 of the Act generally requires all departments and agencies of the Federal Government engaged in any activity that might result in a discharge or runoff of pollutants to surface waters to comply with Federal, state, interstate, and local requirements. Under the Clean Water Act, states generally set water quality standards, and the Environmental Protection Agency and states regulate and issue permits for point-source discharges as part of the National Pollutant Discharge Elimination System permitting program. The Environmental Protection Agency regulations for this program are codified at 40 CFR Part 122, and Nevada rules for this program are codified at Nevada Administrative Code Chapter 445A. If the construction or operation of a Yucca Mountain Project facility or associated transportation route in Nevada would result in point-source discharges, DOE could need to obtain a National Pollutant Discharge Elimination System permit from the State of Nevada Division of Environmental Protection (see Table 11-1, item 10).

Sections 401 and 405 of the Water Quality Act of 1987 added Section 402(p) to the Clean Water Act. Section 402(p) requires the Environmental Protection Agency to establish regulations for the Agency or individual states to issue permits for stormwater discharges associated with industrial activity, including construction activities that could disturb 5 or more acres (40 CFR Part 122). Nevada rules for this program are codified at Nevada Administrative Code Chapter 445A. The Agency has promulgated regulations implementing a separate stormwater permit application process.

Section 404 of the Clean Water Act gives the U.S. Army Corps of Engineers permitting authority over activities that discharge dredge or fill material into waters of the United States. DOE could need to obtain a permit from the Corps for activities associated with a repository at Yucca Mountain if those activities would discharge dredge or fill into any such waters. If the construction or modification of rail lines or highways to the repository included dredge or fill activities or other actions that would discharge dredge or fill into waters of the United States, those activities would also require Section 404 permits. DOE has obtained a Section 404 permit for site characterization-related construction activities it might conduct in Coyote Wash or its tributaries or in Fortymile Wash.

Nevada Revised Statutes: Water Controls, Chapter 445A

These statutes classify the waters of the State, establish standards for the quality of all waters in the State, and specify permitting and notification provisions for stormwater discharges and for other discharges to waters of the State in accordance with provisions of the Federal Clean Water Act. These statutes and regulations in the Nevada Administrative Code also (1) set drinking water standards, specifications for certification, and conditions for issuance of variances and exemptions, (2) set standards and requirements for the construction of wells and other water supply systems, (3) establish the different classes of wells and aquifer exemptions, and (4) establish requirements for well operation and monitoring, plugging, and abandonment activities. Regardless of whether these provisions are applicable, DOE has obtained an Underground Injection Control Permit and a Public Water System Permit for site characterization activities at Yucca Mountain. The Underground Injection Control Permit covers tracers, pump tests, and similar activities. The Public Water System Permit establishes the terms for the provision of potable water.

The Department would install and operate the drinking water system planned for the proposed repository in accordance with Nevada Health Division standards, if applicable, and would obtain a Water System Operating Permit from the Nevada Health Division (see Table 11-1, item 9), if needed. DOE could also need to obtain a General Permit for Storm Water Discharge from the Nevada Division of Water Resources to construct and operate a repository at Yucca Mountain (see Table 11-1, item 10). Any point-source discharges to waters of the State that occurred in the course of Yucca Mountain Project activities could require a National Pollutant Discharge Elimination System permit issued under these provisions. DOE has obtained a general discharge permit from the State for effluent discharges to the ground surface during site characterization.

Nevada Revised Statutes: Adjudication of Vested Water Rights; Appropriation of Public Waters, Chapter 533; Underground Water and Wells, Chapter 534

These statutes and accompanying regulations in the Nevada Administrative Code establish permitting procedures for appropriating public waters of the State, including underground waters, for beneficial use.

DOE has obtained temporary permits for the use of underground water from several wells during site characterization.

It is the policy of the United States Government to apply for water in accordance with state laws. In 1997, DOE applied for an appropriation of water to fulfill the purpose of the NWPA, for the proposed repository in accordance with the provisions of Chapters 533 and 534 of the Nevada Revised Statutes. The Nevada State Engineer denied the DOE water appropriation applications, and DOE appealed the denial in court. The denial is being litigated. On October 15, 2001, the United States Court of Appeals for the Ninth Circuit set the matter for trial in the U.S. District Court for the State of Nevada (No. 00-17330, D.C. No. CV-00-268-RLH).

Chapter 534 of the Nevada Revised Code establishes requirements applicable to drilling, construction, and plugging of wells for extraction of underground water.

Executive Order 11988, *Floodplain Management*

This Order directs Federal agencies to establish procedures to ensure that any Federal action undertaken in a floodplain considers the potential effects of flood hazards and floodplain management and avoids floodplain impacts to the extent practicable. For its site characterization activities, DOE conducted a floodplain assessment (see Appendix L) in accordance with this Order (DIRS 103189-DOE 1992, all) and DOE implementing regulations (10 CFR Part 1022).

Compliance With Floodplain/Wetlands Environmental Review Requirements (10 CFR Part 1022)

Federal regulations (10 CFR Part 1022) establish policy and procedures for implementing Executive Order 11988, *Floodplain Management*, and for discharging DOE responsibilities regarding the consideration of floodplain/wetlands factors in DOE planning and decisionmaking. These regulations also establish DOE procedures for identifying proposed actions located in floodplains, providing opportunity for early public review of such proposed actions, preparing floodplain assessments, and issuing statements of findings for actions in a floodplain. The rules apply to all DOE proposed floodplain actions.

If DOE determines that an action it proposes would take place wholly or partly in a floodplain, it is required to prepare a notice of floodplain involvement and a floodplain assessment containing a project description, a discussion of floodplain effects, alternatives, and mitigations. For a proposed floodplain action for which a National Environmental Policy Act document such as an environmental impact statement or an environmental assessment is required, DOE is to include the floodplain assessment in the document. For floodplain actions for which DOE does not have to prepare such a document, the Department is to issue a separate document as the floodplain assessment. After the conclusion of public comment, DOE is to reevaluate the practicability of alternatives and of mitigation measures, considering all substantive comments.

If it finds that no practicable alternative to locating in the floodplain is available, DOE must design or modify its action to minimize potential harm to and within the floodplain. For actions in a floodplain, DOE must publish a statement of findings of three pages or less containing a brief description of the proposed action, a location map, an explanation indicating the reason for locating the action in the floodplain, a list of alternatives considered, a statement indicating whether the action conforms to applicable State or local floodplain protection standards, and a brief description of steps DOE will take to minimize potential harm to or within the floodplain. For floodplain actions that require the preparation of an EIS, the Final EIS can incorporate the statement of findings. Before implementing a proposed floodplain action, DOE must endeavor to allow at least 15 days of public review of the statement of findings.

Appendix L contains a statement of findings on the potential for repository construction and operation to affect floodplains. Appendix L also contains a floodplain/wetlands assessment that examines the effects of proposed repository construction and operation and potential construction of a rail line or intermodal transfer station. The assessment includes discussion of:

1. Floodplains near Yucca Mountain (Fortymile Wash, Busted Butte Wash, Drillhole Wash, and Midway Valley Wash); there are no delineated wetlands at Yucca Mountain.

2. What is known about floodplains and areas that might have wetlands (for example, springs and riparian areas) along potential rail corridors in Nevada and at intermodal transfer station locations associated with heavy-haul truck routes. If DOE selected rail as the mode of spent nuclear fuel and high-level radioactive waste transport in Nevada, it would select one of the rail corridors, and would prepare a more detailed floodplains/wetlands assessment of the selected corridor. If DOE selected heavy-haul truck as the mode of transport for spent nuclear fuel and high-level radioactive waste in Nevada, it would select one of five heavy-haul truck routes and one of three intermodal transfer stations, and would prepare a more detailed floodplain/wetlands assessment of the selected heavy-haul truck route and the associated intermodal transfer station.

11.2.3 HAZARDOUS MATERIALS PACKAGING, TRANSPORTATION, AND STORAGE

Roles of U.S. Department of Transportation and Nuclear Regulatory Commission in Regulating the Transportation of Radioactive Materials

The U.S. Department of Transportation and Nuclear Regulatory Commission share primary responsibility for regulating safe transportation of radioactive materials in the United States. The Department of Transportation has responsibility to develop and implement transportation safety standards for hazardous materials, including radioactive materials. In Title 49 of the Code of Federal Regulations, the Department of Transportation has established standards and requirements for packaging, transporting, and handling radioactive materials for all modes of transportation, including standards for labeling, shipping papers, placarding, loading and unloading, allowable radioactive levels, and limits for contamination of packages and vehicles, among other requirements. The regulations also specify safety requirements for vehicles and transportation operations, training for personnel who perform handling and transportation of hazardous materials, and liability insurance requirements for carriers.

The Nuclear Regulatory Commission regulates the packaging- and transportation-related operations of its licensees, including commercial shippers of radioactive materials. It sets design and performance standards for packaging (shipping casks) that carry materials with higher levels of radioactivity. The Department of Transportation, by agreement with the Nuclear Regulatory Commission, accepts the Commission standards of 10 CFR Part 71 for packaging. The Nuclear Regulatory Commission also establishes safeguards and security regulations to minimize the possibility of theft, diversion, or attack on shipments of radioactive materials (10 CFR Part 73). Title 10 of the Code of Federal Regulations details these requirements. As required by the NWPA (Section 180), carriers would make all shipments to Yucca Mountain in Nuclear Regulatory Commission-certified packages and in accordance with Commission regulations on advance notification of state and local governments. Appendix M contains a detailed discussion of regulatory responsibilities for transportation activities.

Hazardous Materials Transportation Act (49 U.S.C. 1801)

The Hazardous Materials Transportation Act gives the U.S. Department of Transportation authority to regulate the transport of hazardous materials, including radioactive materials such as those that would be transported to the proposed Yucca Mountain Repository from 72 commercial and 5 DOE sites. Department of Transportation regulations (49 CFR Parts 171 through 180) would require the identification of hazardous materials during transportation to a repository at Yucca Mountain, set forth rules for the selection of routes that carriers must use when transporting such materials, and provide guidance to states in designating preferred routes.

Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C. 1001 *et seq.*)

Under Subtitle A of the Emergency Planning and Community Right-to-Know Act (also known as "SARA Title III"), Federal facilities, including a repository at Yucca Mountain, must provide information on hazardous and toxic chemicals to state emergency response commissions, local emergency planning committees, and the Environmental Protection Agency. The goal of providing this information is to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances. The required information includes inventories of specific chemicals used or stored and descriptions of releases that occur from sites. This law, implemented at 40 CFR Parts 302 through 372, requires agencies to provide material safety data sheet reports, emergency and *hazardous chemical* inventory reports, and toxic chemical release reports to appropriate local, state, and Federal agencies. DOE has been complying with the provisions of the Emergency Planning and Community Right-to-Know Act and with regulations for maintaining and using inventories of chemicals for site characterization activities. If the proposed repository received a license, DOE would continue to comply with such provisions, as applicable, in storing and using chemicals for project activities.

Nevada Revised Statutes: Hazardous Materials, Chapter 459

A Nevada Hazardous Materials Storage Permit could be required to store hazardous materials in quantities greater than those specified in the Uniform Fire Code. To receive such a permit, if sought, DOE would submit an application to the Nevada State Fire Marshal (Nevada Revised Statutes, Chapter 477) that describes its plans for the storage of hazardous materials in excess of specified quantities (see Table 11-1, item 19). If permit renewal was sought each year, DOE would have to submit an annual report to the State Fire Marshal that complied with the reporting requirements of the Federal Emergency Planning and Community-Right-to-Know Act, Sections 302, 311, and 312. Regardless of whether these provisions are applicable, DOE has obtained a permit from the State Fire Marshal for the storage of flammable materials during site characterization activities.

Nuclear Regulatory Commission Radioactive Materials Packaging and Transportation Regulations (10 CFR Parts 71 and 73)

Under 10 CFR Part 71, the Nuclear Regulatory Commission regulates the packaging and transport of spent nuclear fuel for its licensees, which include commercial shippers of radioactive material and the DOE Office of Civilian Radioactive Waste Management. In addition, under an agreement with the U.S. Department of Transportation, the Commission sets the standards for packages containing Type B quantities of radioactive materials, including high-level radioactive waste and spent nuclear fuel. Type B packages are designed and built to retain their radioactive contents in both normal and accident conditions.

The demonstration of compliance with these requirements applies a combination of simple calculational methods, computer modeling techniques, and physical testing to the design features of the package. An applicant presents the results of the analyses and tests to the Nuclear Regulatory Commission in a Safety Analysis Report for Packaging, which the Commission, after review, approves by issuing a Certificate of Compliance. This certificate would be required for the use of a package (cask) to ship spent nuclear fuel or high-level radioactive waste to the repository.

The regulations at 10 CFR Part 73 govern safeguards and physical security during the transit of shipments of spent nuclear fuel. These regulations specify requirements for vehicles, carrier personnel, communications, notification of state governors, escorts, and route planning for such shipments.

Department of Transportation Hazardous Materials Packaging and Transportation Regulations (49 CFR Subchapter C – Hazardous Materials Regulations, Parts 171 Through 180)

The Department of Transportation regulates the shipments of hazardous materials, including spent nuclear fuel and high-level radioactive waste, in interstate and intrastate commerce by land, air, and navigable water. As outlined in a 1979 Memorandum of Understanding with the Nuclear Regulatory Commission (44 *FR* 38690, July 2, 1979), the Department of Transportation specifically regulates carriers of spent nuclear fuel and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. It also regulates the labeling, classification, and marking of transportation packages for radioactive materials.

Department of Transportation regulations include requirements for carriers, drivers, vehicles, routing, packaging, labeling, marking, placarding of vehicles, shipping papers, training, and emergency response. The requirements specify the maximum dose rate associated with radioactive material shipments and the maximum allowable levels of radioactive surface contamination on packages and vehicles.

The public highway routing regulations of the Department of Transportation are prescribed in 49 CFR Part 397. The objectives of the regulations are to reduce the impacts of transporting highway route-controlled quantities of radioactive materials to establish consistent and uniform requirements for route selection, and to identify the role of state and local governments in the routing. The requirements at 49 CFR 173.403(l) contain a complete definition of *Highway Route-Controlled Quantities of Radioactive Material*.

Shipping casks transported by legal-weight trucks typically would contain about 300,000 curies of radionuclides, and rail casks typically would contain larger quantities. These regulations attempt to reduce potential hazards by requiring the use of routes that avoid populous areas and minimize travel times. At present, the Department of Transportation does not regulate the routing of rail shipments of radioactive materials. Department of Transportation regulations also include requirements to protect the health and safety of transportation workers.

11.2.4 CONTROL OF POLLUTION

Pollution Prevention Act of 1990 (42 U.S.C. 13101 *et seq.*)

The Pollution Prevention Act of 1990 establishes a national policy for waste management and pollution control that focuses first on source reduction, then on environmentally safe recycling, treatment, and disposal. DOE requires each of its sites to establish specific goals to reduce the generation of waste. If the Department built and operated a repository at the Yucca Mountain site, it would implement an appropriate pollution prevention plan. DOE has implemented a pollution prevention plan for site characterization activities. DOE would update this plan to include construction, operation and monitoring, and closure activities if the repository received a license.

Comprehensive Environmental Response, Compensation, and Liability Act, as amended (42 U.S.C. 9601 *et seq.*)

The Comprehensive Environmental Response, Compensation, and Liability Act, as amended by the Superfund Amendments and Reauthorization Act, authorizes the Environmental Protection Agency to require responsible site owners, operators, arrangers, and transporters to clean up releases of hazardous substances, including certain radioactive substances. Under this Act, the Environmental Protection Agency would have the authority to regulate hazardous substances, including certain radioactive materials, at the Yucca Mountain Repository in the event of a release or a "substantial threat of a release" of those materials from the repository. Releases greater than reportable quantities would be reported to the National Response Center.

Standards for Protection Against Radiation (10 CFR Part 20)

The purpose of 10 CFR Part 20 is to provide standards and procedures for protection against radiation. Provisions of 10 CFR Part 20 address repository occupational dose limits, public dose limits, survey and monitoring procedures, exposure control in restricted areas, respiratory protection and controls, precautionary procedures, and related topics.

Low-Level Radioactive Waste Policy Amendments Act of 1985 (P.L. 99-240)

Under the Low-Level Radioactive Waste Policy Amendments Act of 1985 (P.L. 99-240), DOE is responsible for disposal of any low-level waste generated by operations at the proposed Yucca Mountain Repository. Such waste would be considered DOE-owned and -generated waste.

On February 25, 2000, DOE issued a Record of Decision (65 *FR* 10061) to establish regional low-level waste disposal at the Hanford Site and Nevada Test Site that would be available to all DOE sites. DOE would ensure that Yucca Mountain is an approved generator in accordance with the requirements of Nevada Test Site waste acceptance criteria prior to disposal of any low-level radioactive waste at the Test Site generated from Yucca Mountain Repository operations.

Resource Conservation and Recovery Act, as amended (42 U.S.C. 6901 *et seq.*)

The treatment, storage, and disposal of hazardous and nonhazardous waste is regulated in accordance with the provisions of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments of 1984, and applicable state laws.

Environmental Protection Agency regulations implementing the hazardous waste portions of the Resource Conservation and Recovery Act define hazardous wastes and specify requirements for their transportation, handling, treatment, storage, and disposal (40 CFR Parts 260 through 272). In addition, under current Civilian Radioactive Waste system requirements, DOE could not accept hazardous waste for disposal at Yucca Mountain. Before shipping to Yucca Mountain, DOE would treat materials that contained hazardous components to eliminate the hazardous waste characteristics. Before shipping materials containing hazardous components listed under Subpart D of Part 261 or applicable state requirements, DOE would process any necessary delisting petitions with the appropriate regulatory authorities. If the activities at Yucca Mountain generated hazardous or mixed waste, the Department would not dispose of such waste on the site and would not treat such waste in a manner that required Resource Conservation and Recovery Act permitting, and would not store such waste on the site for more than 90 days. DOE does not expect to need a Resource Conservation and Recovery Act permit for its activities at the proposed repository.

Noise Control Act of 1972, as amended (42 U.S.C. 4901 *et seq.*)

Section 4 of the Noise Control Act directs Federal agencies to carry out programs in their jurisdictions "to the fullest extent within their authority" and in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health and welfare. This law provides requirements related to noise that would be generated by construction, operation, or closure activities associated with the Proposed Action at Yucca Mountain.

Nevada Revised Statutes: Sanitation, Chapter 444

These statutes and regulations in the Nevada Administrative Code establish the standards, permits, and requirements for septic tanks and other sewage disposal systems for single-family dwellings, communities, and commercial buildings. The construction and operation of a sanitary sewage collection system at Yucca Mountain could require the State of Nevada to approve DOE designs and to issue a permit. In connection with site characterization activities, DOE operates a septic system that the State has permitted under these provisions.

These statutes and regulations also set forth the definitions, methods of disposal, special requirements for solid waste collection and transportation standards, and classification of landfills. Onsite disposal of solid waste from a repository at Yucca Mountain could require that DOE obtain an appropriate permit for these activities.

In compliance with the Resource Conservation and Recovery Act, the Environmental Protection Agency has authorized the State of Nevada to regulate the management and disposal of solid, hazardous, and mixed wastes in the State. The Nevada Division of Environmental Protection or an equivalent solid waste management authority would regulate the onsite disposal of nonhazardous solid wastes generated by activities associated with the proposed repository. DOE would manage such waste in accordance with applicable laws and regulations.

Nevada Administrative Code Chapter 444 contains regulations that provide for fees, variances, and permits, and has adopted Environmental Protection Agency regulations (40 CFR Parts 2, 124, and 260 through 270) as part of the code. The regulations could affect any hazardous or mixed waste generated, treated, or stored onsite by activities associated with a proposed repository at Yucca Mountain. DOE would ship any generated hazardous or mixed wastes off the site within 90 days for treatment, storage, and disposal.

Executive Order 12088, *Federal Compliance with Pollution Control Standards*

Executive Order 12088, as amended by Executive Order 12580, *Superfund Implementation Control Standards*, generally directs Federal agencies to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the Clean Air Act, the Noise Control Act, the Clean Water Act, the Safe Drinking Water Act, the Toxic Substances Control Act, and the Resource Conservation and Recovery Act. Compliance with these orders, as applicable, would be required for a range of DOE activities associated with a proposed repository at Yucca Mountain.

Executive Order 12856, *Right to Know Laws and Pollution Prevention Requirements*

This Order directs Federal agencies to reduce and report toxic chemicals entering any waste stream; improve emergency planning, response, and accident notification; and encourage the use of clean technologies and testing of innovative prevention technologies. In addition, the Order states that Federal agencies are persons for purposes of the Emergency Planning and Community Right-to-Know Act (SARA Title III), which requires agencies to meet the requirements of the Act. Compliance with these orders, as applicable, would be required for a range of DOE activities associated with a proposed repository at Yucca Mountain.

11.2.5 CULTURAL RESOURCES

National Historic Preservation Act, as amended (16 U.S.C. 470 *et seq.*)
The National Historic Preservation Act provides for the placement of sites with significant national historic value on the *National Register of Historic Places*. It requires no permits or certifications. DOE would evaluate activities associated with a repository at Yucca Mountain to determine if they would affect historic resources. If required after this evaluation, the Department would consult with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer. Such consultations generally result in the development of an agreement that includes stipulations to be followed to minimize or mitigate potential adverse impacts to a historic resource (see Table 11-1, item 12).

DOE has entered into a programmatic agreement with the Advisory Council on Historic Preservation for implementation of the National Historic Preservation Act for site characterization activities. This agreement requires DOE to consult and interact with Native Americans during site characterization. In compliance with the agreement provisions, Native American representatives from the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone Tribes have reviewed Yucca Mountain activities on the site twice each year. These reviews have been followed by discussions between Native American representatives and DOE personnel, submittal of comments by the Native American representatives, and responses to the comments by DOE.

Archaeological Resources Protection Act, as amended (16 U.S.C. 470aa *et seq.*)
The Archaeological Resources Protection Act requires a permit for excavation or removal of archaeological resources from publicly held or Native American lands (see Table 11-1, item 14). Excavations must further archaeological knowledge in the public interest, and the resources removed are to remain the property of the United States. If a resource is found on land owned by a Native American tribe, the tribe must give its consent before a permit is issued, and the permit must contain terms or conditions requested by the tribe. Requirements of the Archaeological Resources Protection Act would apply to any Yucca Mountain Project excavation activities that resulted in identification of archaeological resources.

American Indian Religious Freedom Act of 1978 (42 U.S.C. 1996)
The American Indian Religious Freedom Act reaffirms Native American religious freedom under the First Amendment and establishes policy to protect and preserve the inherent and constitutional right of Native Americans to believe, express, and exercise their traditional religions. This law ensures the protection of sacred locations and access of Native Americans to those sacred locations and traditional resources that are integral to the practice of their religions. Further, it establishes requirements that would apply to Native American sacred locations, traditional resources, or traditional religious practices potentially affected by the construction and operation of a repository at Yucca Mountain.

Native American Graves Protection and Repatriation Act of 1990 (25 U.S.C. 3001)
The Native American Graves Protection and Repatriation Act directs the Secretary of the Interior to guide the repatriation of Federal archaeological collections and collections that are culturally affiliated with Native American tribes and held by museums that receive Federal funding. Major actions to be taken under this law include (1) the establishment of a review committee with monitoring and policymaking responsibilities, (2) the development of regulations for repatriation, including procedures for identifying lineal descent or cultural affiliation needed for claims, (3) the oversight of museum programs designed to

meet the inventory requirements and deadlines of this law, and (4) the development of procedures to handle unexpected discoveries of graves or grave goods during activities on Federal or tribal land. The provisions of the Act would be invoked if any excavations associated with a repository at Yucca Mountain led to unexpected discoveries of Native American graves or grave artifacts. DOE and the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone Tribes have entered an agreement to address the potential applicability of the Native American Graves Protection and Repatriation Act to artifacts collected during site characterization activities at Yucca Mountain.

Antiquities Act (16 U.S.C. 431 *et seq.*)

The Antiquities Act protects historic and prehistoric ruins, monuments, and objects of antiquity (including paleontological resources) on lands owned or controlled by the Federal Government. If historic or prehistoric ruins or objects were found during the construction or operation of facilities associated with a repository at Yucca Mountain, DOE would have to determine if adverse effects to these ruins or objects would occur. If adverse effects would occur, the Secretary of the Interior would have to grant permission to proceed with the activity (36 CFR Part 296 and 43 CFR Parts 3 and 7) (see Table 11-1, item 13).

Executive Order 13007, *Indian Sacred Sites*

This Order directs Federal agencies, to the extent permitted by law and not inconsistent with agency missions, to avoid adverse effects to sacred sites and to provide access to those sites to Native Americans for religious practices. The Order directs agencies to plan projects to provide protection of and access to sacred sites to the extent compatible with the project.

Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments*

This Order directs Federal agencies to establish regular and meaningful consultation and collaboration with tribal governments in the development of Federal policies that have tribal implications, to strengthen United States government-to-government relationships with Indian tribes, and to reduce the imposition of unfunded mandates on tribal governments.

11.2.6 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Environmental Justice*

This Order directs Federal agencies, to the extent practicable, to make the achievement of environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority and low-income populations in the United States and its territories and possessions. The order provides that the Federal agency responsibilities it establishes are to apply equally to Native American programs.

11.2.7 ECOLOGY AND HABITAT

Endangered Species Act, as amended (16 U.S.C. 1531 *et seq.*)

The Endangered Species Act provides a program for the conservation of threatened and endangered species and the ecosystems on which those species rely. If a proposed action could affect threatened or endangered species or their habitat, the Federal agency must assess the potential impacts and develop measures to minimize those impacts. The agency then must consult formally with the Fish and Wildlife Service (part of the U.S. Department of the Interior) and the National Marine Fisheries Service (part of the Department of Commerce), as required under Section 7 of the Act. The outcome of this consultation would be a biological opinion by the Fish and Wildlife Service or the National Marine Fisheries Service that stated whether the proposed action would jeopardize the continued existence of the species under consideration. If there is a non-jeopardy opinion, but some individuals are killed incidentally as a result of the proposed action, the Services can determine that such losses are not prohibited as long as measures

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outlined by the Services are followed. Regulations implementing the Endangered Species Act are codified at 50 CFR Parts 15 and 402.

There are no known endangered species on the Yucca Mountain site. The desert tortoise is the only threatened species found on the site. The Fish and Wildlife Service previously issued a biological opinion stating that site characterization activities at Yucca Mountain would not jeopardize the continued existence of the desert tortoise (DIRS 104618-Buchanan 1997, p. 16).

The U.S. Fish and Wildlife Service has issued a Biological Opinion (50 CFR 402.6; see Table 11-1, item 18) establishing reasonable and prudent meaures and terms and conditions to ensure that constructing, operating and monitoring, and eventually closing a repository at Yucca Mountain would not jeopardize the continued existence of the desert tortoise (see Appendix O). If the repository was approved, DOE would comply with all provisions of the Biological Opinion, including the reasonable and prudent measures and their implementing terms and conditions. DOE would fulfill the requirements of the Endangered Species Act, as appropriate, with regard to transportation impacts before making a final determination on a transportation route.

Fish and Wildlife Coordination Act, as amended (16 U.S.C. 661, 48 Stat. 401)
The Fish and Wildlife Coordination Act promotes more effectual planning and cooperation between Federal, state, public, and private agencies for the conservation and rehabilitation of the Nation's fish and wildlife and authorizes the Department of the Interior to provide assistance.

Migratory Bird Treaty Act, as amended (16 U.S.C. 703 *et seq.*)
The purpose of the Migratory Bird Treaty Act is to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. It regulates the take and harvest of migratory birds. The Fish and Wildlife Service will review this EIS to determine whether the activities analyzed would comply with the requirements of the Migratory Bird Treaty Act. Studies indicate that no requirements of this Act are applicable to the Yucca Mountain Project.

Bald and Golden Eagle Protection Act, as amended (16 U.S.C. 668-668d)
The Bald and Golden Eagle Protection Act makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States (Section 668, 668c). The Department of the Interior regulates activities that might adversely affect bald and golden eagles. The Fish and Wildlife Service will review this EIS to determine whether the activities analyzed in this EIS would comply with the Bald and Golden Eagle Protection Act. DOE has established a program to ensure compliance with this law during site characterization activities.

National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. 668dd)
The National Wildlife Refuge System Administration Act provides guidelines for the administration and management of lands in the system, including "wildlife refuges, areas for the protection and conservation of fish and wildlife that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas." If use of lands for transportation corridors and facilities such as a rail line or intermodal transfer station associated with a repository at Yucca Mountain could affect lands in the system, DOE would consult with the Fish and Wildlife Service. Regulations implementing the Act are codified at 50 CFR Parts 25 and 27 through 29. The Fish and Wildlife Service will review this EIS to determine if the Proposed Action would comply with the Act. It is DOE policy to place transportation corridors and facilities to avoid existing wildlife refuges.

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Nevada Revised Statutes: Protection and Preservation of Timbered Lands, Trees, and Flora, Chapter 527

These provisions broadly protect the indigenous flora of the State of Nevada. If the State determines that a species or subspecies of native flora is threatened with extinction, that species or subspecies is to be placed on the State list of fully protected species. In general, no member of the species or subspecies may be taken or destroyed unless an authorized State official issues a special permit. Activities associated with a repository at Yucca Mountain arguably could affect such species and could require special permits.

Nevada Revised Statutes: Hunting, Fishing, and Trapping; Miscellaneous Protective Measures, Chapter 503; Nevada Administrative Code, Chapter 503: Sections 010-104, General Provisions

These provisions specify procedures for the classification and protection of wildlife. If the State determines that an animal species is threatened with extinction, the species is to be placed on the State list of fully protected species. In general, no member of the species may be taken or destroyed unless the Nevada Division of Wildlife issues a special permit. Activities associated with a repository at Yucca Mountain arguably could affect such species and could require special permits. Regardless of whether these provisions are applicable, DOE has obtained a permit for site characterization activities from the State of Nevada.

Executive Order 11990, *Protection of Wetlands*

This order directs Federal agencies to avoid new construction in wetlands unless there is no practicable alternative and unless the proposed action includes all practicable measures to minimize harm to wetlands that might result from such use. DOE requirements for compliance with wetlands activity review procedures are codified at 10 CFR Part 1022.

Executive Order 13112, *Invasive Species*

This order directs Federal agencies to act to prevent the introduction of or to monitor and control invasive (non-native) species, to provide for restoration of native species, to conduct research, to promote educational activities, and to exercise care in taking actions that could promote the introduction or spread of invasive species. If a repository were constructed at Yucca Mountain, DOE would comply with provisions of this Executive Order as part of construction, operation and monitoring, and closure activities.

Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*

This Order requires Federal agencies to avoid or minimize the negative impacts of their actions on migratory birds, and to take active steps to protect birds and their habitats. The Order directs each Federal agency taking actions having or likely to have a negative impact on migratory bird populations to work with the U.S. Fish and Wildlife Service to develop an agreement to conserve those birds. The Order directs agencies to avoid or minimize impacts to migratory bird populations, take reasonable steps that include restoring and enhancing habitat, prevent or abate pollution affecting birds, and incorporate migratory bird conservation into agency planning processes whenever possible. The Order also requires environmental analyses of Federal actions to evaluate effects of those actions on migratory birds, to control the spread and establishment in the wild of exotic animals and plants that could harm migratory birds and their habitats, and either to provide advance notice of actions that could result in the take of migratory birds or to report annually to the U.S. Fish and Wildlife Service on the numbers of each species taken during the conduct of agency actions. If a repository was constructed at Yucca Mountain, DOE would comply with provisions of this Executive Order as part of construction, operation and monitoring, and closure activities.

11.2.8 USE OF LAND AND WATER BODIES

Coastal Zone Management Act (16 U.S.C. 1451 *et seq.*)

The purpose of the Coastal Zone Management Act is to preserve, protect, develop, restore, and enhance the resources of the Nation's coastal zone. Resources include wetlands, floodplains, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitat. This law provides for (1) management to minimize the loss of life and property caused by improper development and by the destruction of natural protective features such as beaches, dunes, wetlands, and barrier islands, and (2) improvement, safeguarding, and restoration of the quality of coastal waters, and for protection of existing uses of those waters. The Coastal Zone Management Act requires priority consideration to coastal-dependent uses and orderly processes for siting major facilities related to national defense, energy, fisheries development, recreation, ports and transportation, and the location of new commercial and industrial developments in or adjacent to areas where such development already exists.

The operation of a repository at Yucca Mountain could require the use of barges for transportation of spent nuclear fuel along portions of routes from some storage facilities. In addition, rail corridors, roads, and bridges from some storage facilities could require repair or enhancement before they could support shipment of spent nuclear fuel. DOE would ensure that its activities are consistent with state-specific coastal zone management plans promulgated in accordance with this Act, if applicable. The regulations promulgated under the Act are codified at 15 CFR Part 930.

Rivers and Harbors Act (33 U.S.C. 401 *et seq.*)

The transportation of spent nuclear fuel and high-level radioactive waste could require the construction or modification of road or rail bridges that span navigable waters. The Rivers and Harbors Act prevents the alteration or modification of the course, location, condition, or capacity of any channel of any navigable water of the United States without a permit from the U.S. Army Corps of Engineers. If DOE assumed responsibility for such construction or modifications, it would need to obtain a permit from the U.S. Army Corps of Engineers. Regulations implementing this Act are codified at 33 CFR Part 323.

National Forest Organic Administrative Act (16 U.S.C. 521)

The National Forest Organic Administrative Act establishes the functions and responsibilities of the Forest Service, an agency of the U.S. Department of Agriculture. The Forest Service would be requested to approve the construction of rail lines and roads in Nevada that would be associated with the operation of a repository at Yucca Mountain and that could cross land administered by the Service (16 U.S.C. 1600, 1611 to 1614).

National Forest Management Act of 1976

The National Forest Management Act establishes decision planning and management practices for forests. This law could affect any proposed construction of rail lines or roads associated with the construction or operation of a repository at Yucca Mountain that could cross National Forest lands.

Materials Act of 1947 (30 U.S.C. 601-603)

The Materials Act authorizes land management agencies, such as the Bureau of Land Management and the Forest Service, to make common varieties of sand, stone, and gravel from public lands available to Federal and state agencies under a Free Use Permit (see Table 11-1, item 15). Regulations implementing the Materials Act are codified at 43 CFR Part 3620. DOE has received three free use permits from the Bureau of Land Management to obtain gravel for site characterization activities in a manner compliant with the Materials Act.

Taylor Grazing Act (43 U.S.C. 315-316)

The Taylor Grazing Act establishes the processes by which the Bureau of Land Management grants and administers grazing rights. If a decision is made to construct and operate a repository, a new rail line, or a

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new road on a Bureau of Land Management grazing allotment, DOE would have to acquire a right-of-way grant across the allotment or a withdrawal of the allotment. Regulations implementing the Taylor Grazing Act are codified at 43 CFR Part 4100.

Farmland Protection Policy Act (7 U.S.C. 4201 *et seq.*)
The Farmland Protection Policy Act seeks to minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmlands to nonagricultural uses. Compliance with this law requires concurrence from the Natural Resources Conservation Service of the U.S. Department of Agriculture that proposed activities would not affect farmlands. DOE has completed a consultation with the Natural Resources Conservation Service that determined that a repository at Yucca Mountain would not affect prime or unique farmlands. This EIS assesses the potential construction of a rail line, new roads, or an intermodal transfer station in Nevada to determine if that construction could affect such lands. Regulations implementing the Farmland Protection Policy Act are codified at 7 CFR Part 658.

11.3 Department of Energy Orders

Under the authority of the Atomic Energy Act, DOE is responsible for establishing a comprehensive health, safety, and environmental program for its activities and facilities. The Department has established a framework for managing its facilities through the promulgation of regulations and the issuance of DOE Orders. In general, DOE Orders set forth policies, programs, and procedures for implementing policies. Many DOE Orders contain specific requirements in the areas of radiation protection, nuclear safety and safeguards, and security of nuclear material. Table 11-3 lists DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program.

The Nuclear Regulatory Commission is authorized to license the proposed Yucca Mountain repository. Some DOE Orders overlap or duplicate Nuclear Regulatory Commission repository licensing regulations in whole or in part. Recognizing this, the Department issued DOE HQ Order 250.1*, Civilian Radioactive Waste Management Facilities – Exemption from Departmental Directives.* This Order exempts geologic repository design, construction, operation, and decommissioning from compliance with the provisions of DOE Orders that overlap or duplicate Commission requirements related to radiation protection, nuclear safety (including quality assurance), and safeguard and security of nuclear material. The exemption would apply only to portions of a repository project for which DOE sought a Nuclear Regulatory Commission license. DOE Orders would continue to establish requirements for other activities associated with a repository that fall outside the scope of this exemption, for example in the area of computer security (Order 1360.28).

Through DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees,* the Department has prescribed the Occupational Safety and Health Act standards that contractors are to meet in their work at government-owned, contractor-operated facilities.

A monitored geologic repository at Yucca Mountain would be a nonreactor nuclear facility. DOE Orders 5480.21, *Unreviewed Safety Questions,* 5480.22, *Technical Safety Requirements,* and 5480.23, *Nuclear Safety Analysis Reports,* ordinarily apply to nonreactor nuclear facilities. Because DOE Order 250.1 gives precedence to Nuclear Regulatory Commission rules, DOE Orders 5480.21, 5480.22, and 5480.23, for example, probably would not apply to the repository.

11.4 Potentially Applicable Federal Regulations

Sections 11.2.1 through 11.2.8 and Section 11.3 identify major laws, regulations, and DOE Orders potentially applicable to the construction, operation and monitoring, and closure of a monitored geologic repository. Table 11-4 lists other potentially applicable regulations and orders.

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Table 11-3. DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program (page 1 of 2).

Order	Subject	Description
151.1	Comprehensive Emergency Management System	Establishes requirements for emergency planning, preparedness, response, recovery, and readiness assurance activities and describes the approach for effectively integrating these activities under a comprehensive, all-emergency concept.
231.1	Environment, Safety and Health Reporting	Establishes the requirements and procedures for reporting information with environmental protection, safety, or health protection significance for DOE operations.
232.1	Occurrence Reporting and Processing of Operations Information	Establishes the requirements for reporting and processing occurrences related to safety, health, security, property, operations, and the environment, up to and including emergencies.
250.1	Civilian Radioactive Waste Management Facilities – Exemption from Departmental Directives	Establishes the relationship between DOE directives and Nuclear Regulatory Commission regulations for the Yucca Mountain Project.
420.1A	Facility Safety	Establishes facility safety requirements related to nuclear safety design, criticality safety, fire protection, and natural phenomena hazards mitigation.
425.1	Facility Startup and Restart	Establishes procedures to be followed when a facility is taken from a nonoperational to an operational state.
430.1	Life Cycle Asset Management	Establishes procedures to be followed in all phases of the management of DOE facilities.
435.1	Radioactive Waste Management	Establishes policies and guidelines by which DOE manages radioactive waste, waste byproducts, and radioactively contaminated surplus facilities.
440.1A	Worker Protection Management for DOE Federal and Contractor Employees	Establishes a comprehensive worker protection program that ensures that DOE and its contractor employees have an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE, Federal, and contractor workers with a safe and healthful workplace.
451.1B	National Environmental Policy Act Compliance Program	Establishes DOE internal requirements and responsibilities for implementing the National Environmental Policy Act of 1969, as amended, the Council on Environmental Quality regulations implementing the procedural provisions of the Act (40 CFR Part 1500 *et seq.*), and the DOE procedures that implement it (10 CFR Part 1021).
460.1A	Packaging and Transportation Safety	Establishes requirements and assigns responsibilities for the safe transport of hazardous materials, hazardous substances, hazardous wastes, and radioactive materials.
462.1	Departmental Materials Transportation and Packaging Management	Establishes supplemental policies and requirements for materials transportation and packaging operations.
1300.2A	Department of Energy Technical Standards Program	Establishes policy, assigns responsibility, and provides requirements for development and application of technical standards in DOE facilities, programs, and projects; provides for participation in non-Government standards bodies and for establishment of a DOE Technical Standards Program; and assigns responsibility for the management of the program.

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Table 11-3. DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program (page 2 of 2).

Order	Subject	Description
1360.2B	Unclassified Computer Security Program	Establishes requirements, policies, responsibilities, and procedures for developing, implementing, and sustaining a DOE unclassified computer security program.
3790.1B	Federal Employee Occupational Safety and Health Program	Establishes requirements and procedures to ensure that occupational safety and health standards prescribed pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, and the DOE Organization Act of 1977 provide occupational safety and health protection for DOE contractor employees in Government-owned contractor-operated facilities.
5400.1	General Environmental Protection Program	Establishes environmental protection program requirements, authorities, and responsibilities for DOE operations to ensure compliance with applicable Federal, state, and local environmental protection laws and regulations and with internal DOE policies.
5400.5	Radiation Protection of the Public and the Environment	Establishes standards and requirements for operation of DOE and DOE contractors with respect to protection of members of the public and the environment against undue risk from radiation.
5480.19	Conduct of Operations Requirements for DOE Facilities	Provides requirements and guidelines for DOE elements to use in developing directives, plans, and procedures related to the conduct of operations at DOE facilities.
5484.1	Environmental Protection, Safety, and Health Protection Information Reporting Requirements	Establishes the requirements and procedures for the investigation of occurrences having environmental protection, safety, or health protection significance, and for efficient environmental monitoring of DOE operations.
5610.14	Transportation Safeguards System Program Operations	Establishes DOE policies for and implementation of the management and operation of the Transportation Safeguards System program.
5632.1C	Protection and Control of Safeguards and Security Interests	Establishes policy, responsibilities, and authorities for the protection and control of safeguards and security interests (for example, special nuclear material, vital equipment, classified matter, property, facilities, and unclassified irradiated reactor fuel in transit).
5633.3B	Control and Accountability of Nuclear Materials	Prescribes the minimum DOE requirements and procedures for control and accountability of nuclear materials at DOE-owned and -leased facilities and DOE-owned nuclear materials at facilities that are exempt from licensing by the Nuclear Regulatory Commission. Would apply to materials destined for a repository before the materials reached the repository.

Table 11-4. Other potentially applicable Federal regulations, orders, standards, and memoranda (page 1 of 3).

Document Number	Title[a]
Code of Federal Regulations	
10 CFR Part 2	Rules of Practice for Domestic Licensing Proceedings and Issuance of Orders
10 CFR Part 19	Notices, Instructions and Reports to Workers: Inspection and Investigations
10 CFR Part 40	Domestic Licensing of Source Material
10 CFR Part 51	Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions
10 CFR Part 75	Safeguards on Nuclear Material-Implementation of US/IAEA Agreement
10 CFR Part 100	Reactor Site Criteria
10 CFR Part 707	Workplace Substance Abuse Programs at DOE Sites
10 CFR Part 830	Nuclear Safety Management
10 CFR Part 835	Occupational Radiation Protection
10 CFR Part 1021	National Environmental Policy Act Implementing Procedures
10 CFR Part 1022	Compliance with Floodplain/Wetlands Environmental Review Requirements
29 CFR Part 1926	Safety and Health Regulations for Construction
29 CFR Part 1960	Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters
30 CFR Part 57	Safety and Health Standards, Underground Metal and Nonmetal Mines
33 CFR Part 323	Permits for Discharges of Dredged or Fill Material into Waters of the United States
33 CFR Chapter I	Coast Guard Department of Transportation (Parts 1-199)
36 CFR Part 296	Permits to Proceed (Objects of Antiquity)
36 CFR Part 800	Protection of Historic and Cultural Properties
40 CFR Part 50	National Primary and Secondary Ambient Air Quality Standards
40 CFR Part 60	Standards of Performance for New Stationary Sources
40 CFR Part 61	National Emission Standards for Hazardous Air Pollutants
40 CFR Part 63	National Emission Standards for Hazardous Air Pollutants for Source Categories
40 CFR Part 122	EPA Administered Permit Programs: The National Pollutant Discharge Elimination System
40 CFR Part 125	Criteria and Standards for the National Pollutant Discharge Elimination System
40 CFR Part 133	Secondary Treatment Regulation
40 CFR Part 136	Guidelines Establishing Test Procedures for the Analysis of Pollutants
40 CFR Part 141	National Primary Drinking Water Regulations
40 CFR Part 142	National Primary Drinking Water Regulations Implementation
40 CFR Part 143	National Secondary Drinking Water Regulations
40 CFR Part 246	Source Separation for Materials Recovery Guidelines
40 CFR Part 257	Criteria for Classification of Solid Waste Disposal Facilities and Practices
40 CFR Part 260	Hazardous Waste Management System: General
40 CFR Part 261	Identification and Listing of Hazardous Waste
40 CFR Part 262	Standards Applicable to Generators of Hazardous Waste
40 CFR Part 263	Standards Applicable to Transporters of Hazardous Waste
40 CFR Part 264	Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
40 CFR Part 265	Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
40 CFR Part 268	Land Disposal Restrictions
40 CFR Part 280	Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks
40 CFR Part 503	Standards for the Use or Disposal of Sewage Sludge
40 CFR Part 747	Metalworking Fluids
40 CFR Part 761	Polychlorinated Biphenyls Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions
40 CFR Parts 1500 to 1508	Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act

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Table 11-4. Other potentially applicable Federal regulations, orders, standards, and memoranda (page 2 of 3).

Document Number	Title[a]
Code of Federal Regulations (continued)	
41 CFR Part 101	Federal Property Management Regulations
43 CFR Parts 3 and 7	Preservation of Antiquities, Protection of Archaeological Resources
43 CFR Part 2300	Land Withdrawal
43 CFR Part 3620	Free Use Permit
43 CFR Part 4100	Grazing Administration, Exclusive of Alaska
49 CFR Part 40	Procedures for Transportation Workplace Drug Testing Programs
49 CFR Part 171	General Information, Regulations and Definitions
49 CFR Part 172	Hazardous Materials Table, Special Provisions, Hazardous Materials Communications Requirements and Emergency Response Information Requirements
49 CFR Part 173	Shippers – General Requirements for Shipments and Packagings
49 CFR Part 174	Carriage by Rail
49 CFR Part 176	Carriage by Vessel
49 CFR Part 177	Carriage by Public Highway
49 CFR Part 178	Shipping Container Specifications
49 CFR Part 180	Continuing Qualification and Maintenance of Packagings
49 CFR Part 392	Driving of Motor Vehicles
49 CFR Part 393	Parts and Accessories Necessary for Safe Operation
49 CFR Part 395	Hours of Service for Drivers
50 CFR Part 17	Endangered and Threatened Wildlife and Plants
50 CFR Part 400	Endangered Species Act
50 CFR Part 402	Interagency Cooperation – Endangered Species Act of 1973, as Amended
Executive Orders	
Executive Order 11514	National Environmental Policy Act, Protection and Enhancement of Environmental Quality
Executive Order 11988	Floodplain Management
Executive Order 11990	Protection of Wetlands
Executive Order 12856	Right to Know Laws and Pollution Prevention Requirements
Executive Order 12898	Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
Executive Order 13007	Indian Sacred Sites
Executive Order 13084	Consultation and Coordination with Indian Tribal Governments
Executive Order 13132	Federalism
Other documents, orders and directives	
AAR Rule 91	1993 Field Manual of Association of American Railroads Interchange Rules (AAR Interchange Rule 91, Weight Limitations)
BLM Manual, Sec. 9113	Bureau of Land Management Manual, Road Standards
DOE Order 430.1	Life Cycle Asset Management
DOE Order 3790.1	Federal Employees Occupational Safety and Health Program
DOE Order 5480.4	Environmental Protection, Safety, and Health Protection Standards
DOE Order 5632.1	Protection Program Operation
DOE/EA-0179	Environmental Assessment Waste Form Selection for Savannah River HLW
DOE/EH-0256T	DOE Radiological Control Manual
DOE/RW-0184	Characteristics of Potential Repository Wastes, Volumes 1-4
DOE/RW-0194P	Records Management Policies and Requirements
DOE/RW-0328P	Acceptance Priority Ranking
DOE/RW-0333P	OCRWM Quality Assurance Requirements and Description
DOE/RW-0457	1995 Acceptance Priority Ranking and Annual Capacity Report
DOE-STD-1020	Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities
DOE-STD-1021	Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems and Components
DOE-STD-1022	Natural Phenomena Hazards Site Characterization Criteria

Table 11-4. Other potentially applicable Federal regulations, orders, standards, and memoranda (page 3 of 3).

Document Number	Title[a]
Other documents, orders and directives (continued)	
DOE-STD-1023	Natural Phenomena Hazards Assessment Criteria (Draft)
DOE-STD-1024	Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites
DOE-STD-1062	Ergonomic and Human Factors Design Criteria[b]
Fed-STD-795	Uniform Federal Accessibility Standards
GSA-FSS-W-A-450/1-17	General Service Administration Interim Federal Specification
MOA DP/RW	Policy for Shipping Defense High-Level Waste (DHLW) to a Civilian Radioactive Waste Repository
MOA RW/NS	Nuclear Safety Requirement
MOU DOE/DOL	Mining Safety
NRC RG 1.13	Spent Fuel Storage Facility Design Basis
NRC RG 1.76	Design Basis Tornado for Nuclear Power Plants
NRC RG 8.8	Information Relevant to Ensuring That Occupational Radiation Exposure at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable
NRC RG 8.10	Operating Philosophy for Maintaining Occupational Radiation Exposure As Low As Is Reasonably Achievable
NUREG 0700	Guidelines for Control Room Design Reviews
NUREG 0856	Final Technical Position on Documentation of Computer Codes for High-Level Waste Management
Presidential Memo (04/30/85)	Dispose of Defense Waste in a Commercial Repository

a. IAEA = International Atomic Energy Agency; EPA = Environmental Protection Agency; HLW = high-level radioactive waste; OCRWM = Office of Civilian Radioactive Waste Management.

b. This standard is complete, but has not been formally published at this time. However, it is included here as a source because it consists of a compilation of requirements from accepted sources. Those sources include standards from the Code of Federal Regulations, Nuclear Regulatory Commission regulations, and military, American National Standards Institute, National Aeronautics and Space Administration, and Electric Power Research Institute standards, as well as recognized design handbooks and guides that govern standard engineering practice.

REFERENCES

104618 Buchanan 1997 — Buchanan, C.C. 1997. "Final Biological Opinion for Reinitiation of Formal Consultation for Yucca Mountain Site Characterization Studies." Letter from C.C. Buchanan (Department of the Interior) to W. Dixon (DOE/YMSCO), July 23, 1997, File No. 1-5-96-F-307R. ACC: MOL.19980302.0368.

103189 DOE 1992 — DOE (U.S. Department of Energy) 1992. *Environmental Assessment for the Shipment of Low Enriched Uranium Billets to the United Kingdom from the Hanford Site, Richland, Washington.* DOE/EA-0787. Richland, Washington: U.S. Department of Energy. ACC: MOL.20010730.0389.

100018 National Research Council 1995 — National Research Council 1995. *Technical Bases for Yucca Mountain Standards.* Washington, D.C.: National Academy Press. TIC: 217588.

12

References

12. REFERENCES

Chapter 12 of the Draft Environmental Impact Statement (EIS) listed all of the references cited in Chapters 1 through 11 of that document. For this Final EIS, the U.S. Department of Energy (DOE or the Department) has put a list of references at the end of each chapter that is specific to that chapter. DOE feels that this makes it easier for the reader to find the complete citations relevant to each chapter. Information regarding the availability of these references can be found in the DOE Reading Rooms (as listed in Appendix D) or on the internet at the Yucca Mountain Project website at *http://www.ymp.gov*.

13

Preparers, Contributors, and Reviewers

13. PREPARERS, CONTRIBUTORS, AND REVIEWERS

13.1 Preparers and Contributors

This chapter lists the individuals who filled primary roles in the preparation of this final environmental impact statement (EIS). Jane R. Summerson of the U.S. Department of Energy (DOE) Yucca Mountain Project Office directed the preparation of the EIS. Primary support and assistance to DOE was provided by the EIS Preparation Team, led by Joseph W. Rivers, Jr., of Jason Technologies Corporation; other members of the team included Tetra Tech NUS Inc., Battelle, and Dade Moeller & Associates. Judith A. Shipman coordinated the work of the Jason Technologies Corporation production team (Elisa Aguilar, Dalene Glanz, Laura Hall, Virginia Hutchins, Robin Klein, Evelyn Mayfield, Aaron McKinnon, and Janet McCreary). Dawn Siekerman supervised the EIS recordkeeping and reference support team (Marcia Gershin, Angelica Marquez, and Jessi Pagel). Glenn Caprio, assisted by Barbara Rhoads, provided scheduling support. Cynthia Langdale and Kathy Grebstad, under the supervision of Diane Morton, ensured EIS revision control accuracy.

DOE provided direction to the EIS Preparation Team, which was responsible for developing the analytical methodology and alternatives, coordinating the work tasks, performing the impact analyses, and producing the document. DOE was responsible for data quality, the scope and content of the EIS, and issue resolution and direction.

In addition, the Management and Operating Contractor to the DOE Yucca Mountain Site Characterization Office (Bechtel SAIC Corporation and its subcontractors) assisted in the preparation of supporting documentation and information for the EIS, as did Sandia, Argonne, and Oak Ridge National Laboratories. These organizations worked closely with the EIS Preparation Team under DOE direction.

DOE independently evaluated all supporting information and documentation prepared by these organizations. Further, DOE retained the responsibility for determining the appropriateness and adequacy of incorporating any data, analyses, and results of other work performed by these organizations in the EIS. The EIS Preparation Team was responsible for integrating such work into the EIS.

As required by Federal regulations (40 CFR 1506.5c), Jason Technologies Corporation and its subcontractors have signed NEPA Disclosure Statements in relation to the work they performed on this EIS. These statements appear at the end of this chapter.

Name	Education	Experience	Responsibility
U.S. Department of Energy			
Jane R. Summerson	Ph.D., Geology, 1991 M.S., Geobiology, 1985 M.A., Anthropology, 1978 B.A., Anthropology, 1977	11 years – waste management projects with the DOE Office of Civilian Radioactive Waste Management	Document Manager
Robin L. Sweeney	Ph.D. student, Environmental Science and Public Policy M.S., Geosciences, 1987 B.S., Biological Sciences, 1980	22 years – hazardous and nuclear waste field; waste management, RCRA/CERCLA facility assessments, sampling and monitoring, project/program management, laboratory research	Senior Technical Specialist; NEPA Compliance Officer

Name	Education	Experience	Responsibility
Joseph D. Ziegler	B.S., Engineering (Nuclear), 1975	26 years – nuclear engineering, nuclear safety, environmental assessment, and project management; Federal and commercial nuclear projects	Senior Technical Advisor
M. Jozette Booth	B.S., Business Administration	18 years – transportation and policy analysis, communications and public participation, intergovernmental and Native American consultations	Technical lead for transportation and American Indian Programs
Wendy R. Dixon	Postgraduate studies, Geology and Environmental Science M.B.A., Business B.A., Sociology	21 years – management of nuclear-related projects; 14 years – regulatory compliance and field management; 6 years – safety and health	Senior Advisor for Environmental Policy
Kenneth J. Skipper	B.S., Geology, 1984	19 years – geotechnical/ environmental project management; Federal civil works projects; planning, construction, operations, and performance monitoring	Document Manager until March 2001
Final EIS Preparation Team			
Joseph W. Rivers, Jr. Jason Technologies Corporation	B.S., Mechanical Engineering, 1982	19 years – commercial and DOE nuclear projects; design, systems engineering, safety analysis, and regulatory compliance	Project Manager
David R. Wayman Jason Technologies Corporation	M.B.A., Business Administration, 1988 B.S., Construction Technology, 1980	20 years – commercial and DOE projects; construction engineering, nuclear safety analysis, environment compliance and permitting	Deputy Project Manager; Lead, Comment-Response Document
Diane E. Morton Jason Technologies Corporation	B.S., Chemical Engineering, 1979	21 years – DOE nuclear and environmental projects; project/program management, assessments, planning	Document Manager
John O. Shipman Jason Technologies Corporation	B.A., English Literature, 1966	35 years – NEPA documentation, technical writing and editing, publications management; 10 years – public participation	Document Production Manager, Editor; Comment-Response Document

Name	Education	Experience	Responsibility
Dawn Siekerman Jason Technologies Corporation	B.S., Biology, 1985	16 years – 3 years NEPA document preparation, 6 years environmental compliance/mixed waste project coordination/ quality assurance, 7 years inorganic chemistry	Records/Data Manager
Roseanne Aaberg Battelle – Pacific Northwest National Laboratories	B.S., Chemical Engineering, 1976	24 years – geological analysis; 11 years – environmental health physics	Air quality
Thomas Anderson Battelle Memorial Institute	B.S., Botany, 1973	28 years – preparation of DOE NEPA documents	Transportation
Pixie Baxter Tetra Tech NUS Inc.	M.B.A., Economics, 1981 B.A., Art History	20 years – multidisciplinary economic and business experience including 15 years as Economics College faculty member	Lead analyst, socioeconomics
William J. Berry Jason Technologies Corporation	Ph.D., Entomology, 1988 M.S., Biology, 1983 B.S., Biology, 1981	12 years – NEPA documents, ecological risk assessments, and habitat management plans	Lead analyst, biological resources
Ralph E. Best Jason Technologies Corporation	M.B.A., 1981 M.S., Electrical Engineering, 1970 B.S., Engineering Physics, 1964	36 years – energy, transportation, and environmental technology	Lead analyst, transportation
Carol Cole Jason Technologies Corporation	B.S., Experimental Psychology, 1967	20 years – NEPA documents, communications, public participation, media planning	Comment-Response Document
William J. Craig Dade Moeller & Associates	M.S., Planning, 1977 B.S., Forestry, 1972	22 years – environmental project management, nuclear fuel planning and analyses, natural resource management, and nuclear powerplant siting and relicensing	Comment-Response Document
David Crowl Jason Technologies Corporation	B.A., Computer Science, 1985	16 years – editing and document production	Editor

Name	Education	Experience	Responsibility
Keith D. Davis, PE Jason Technologies Corporation	M.S., Civil and Environmental Engineering, 1976 B.S., Civil Engineering, 1973	25 years – civil and environmental engineering; waste management; facility permitting and closure; site investigations, feasibility studies, and remedial action planning; 8 years – NEPA documentation	Hydrology; soils
Peter R. Davis Jason Technologies Corporation	Oak Ridge School of Reactor Technology, 1962 B.S. Physics, 1961	38 years – nuclear reactor and nuclear facility safety analysis and risk assessment	Lead analyst, accidents, inventory
Ted B. Doerr Jason Technologies Corporation	Ph.D., Wildlife and Fisheries Sciences, 1988 M.S., Range Science, 1980 B.S., Wildlife and Fisheries Sciences, 1977	19 years – NEPA implementation, ecology, environmental and ecological risk assessments, mitigation development, and regulatory compliance	Project Manager, Draft EIS
Sara A. Doersam Jason Technologies Corporation	B.A., Psychology, 1982	9 years – editing and publishing; 14 years – health administration	Editor
Paul W. Eslinger Battelle – Pacific Northwest National Laboratories	Ph.D., Statistics, 1983 M.A., Mathematics, 1978 B.S., Mathematics, 1976	18 years – environmental risk and human and ecological risk analysis	Long-term performance analysis
Suzanne Fiscus Jason Technologies Corporation	B.S., Mechanical Engineering, 1987	12 years - DOE nuclear projects; safety analysis, design and testing, waste characterization	Offsite manufacturing of disposal containers, shipping casks, drip shields, emplacement pallets, and related components
Philip C. Fulmer Dade Moeller & Associates	Ph.D., Nuclear Engineering, 1993 M.S., Health Physics, 1990 B.S., Health Physics, 1989	7 years – preparation of NEPA documents; 12 years – radiation protection, internal radiation dosimetry, external radiation dosimetry	Lead analyst, cumulative impacts
Gary Gunter Tetra Tech NUS Inc	B.S., Geology, 1984	5 years – preparation of NEPA documents; 13 years – assessments, remedial action	Lead analyst, land use; aesthetics

Name	Education	Experience	Responsibility
Ernest C. Harr, Jr. Jason Technologies Corporation	B.S., Zoology/Chemistry, 1977	12 years – preparation of NEPA documents; acted as DOE EM Headquarters NEPA Compliance Officer; reviewed many DOE waste management NEPA documents.	Deputy Project Manager, Draft EIS; Project Manager, 1999-2000
Mary N. Hoganson Tetra Tech NUS Inc.	M.S., Biology, 1989 B.S., Biology, 1984	14 years – waste management and waste minimization; 6 years – NEPA document preparation	Lead analyst, waste management and hazardous materials
Richard H. Holder Jason Technologies Corporation	M.B.A., Business Administration, 1986 M.S., Electrical Engineering, 1970 B.S., Electrical Engineering, 1966	33 years – team and line management for nuclear utility, industrial, and overseas projects	Proposed Action, alternatives, summary of findings and comparison
R. Kingsley House, PE Jason Technologies Corporation	M.S., Engineering Science/Nuclear Option, 1963 B.S., Mechanical Engineering, 1960 Nevada Registration No. 13062, 1997	40 years – nuclear and non-nuclear facility design, construction, testing, and operation; hazards analysis, safety analysis, and environmental impact analysis	Lead analyst, utilities, energy, materials, and site services; offsite manufacturing of disposal containers, shipping casks, drip shields, waste package supports, and related components
Tracy A. Ikenberry, CHP Dade Moeller & Associates	M.S., Radiology & Radiation Biology, 1982 B.A., Biology, 1979	19 years - environmental and occupational radiation protection; 7 years - NEPA document management and technical analysis	Lead analyst, short-term repository impacts, air quality; human health and safety
David H. Lester Jason Technologies Corporation	Ph.D., Chemical Engineering, 1969 M.S., Chemical Engineering, 1966 B.Che., Chemical Engineering, 1964	28 years – hazardous and nuclear waste management; nuclear Safety Analysis Reports, hazards analysis of waste storage operations, risk assessment of low-level nuclear waste burial operations, groundwater contamination transport modeling, performance assessment of high-level nuclear waste systems, design of treatment systems, design and analysis of high-level waste packages, and soil remediation studies	Lead Analyst, long-term performance

Name	Education	Experience	Responsibility
Steven Maheras Battelle Memorial Institute	Ph.D., Health Physics, 1988 M.S., Health Physics, 1985 B.S., Zoology, 1982 Certified Health Physicist, 1992	13 years – transportation risk assessment and radiological assessment; environmental and occupational radiation protection	Transportation
Thomas McSweeney Battelle Memorial Institute	Ph.D., Chemical Engineering, 1967 M.A., Mathematics, 1964 M.S., Chemical Engineering, 1961 B.S., Chemical Engineering, 1960	34 years – risk and safety analysis; 14 years – transportation risk analysis	Transportation
William E. Nichols Battelle – Pacific Northwest National Laboratories	M.S., Civil Engineering, 1990 B.S., Agricultural Engineering, 1987	12 years – subsurface flow and transport modeling and model development, environmental dispersion modeling and model development, probabilistic risk assessment, total systems modeling for geologic radioactive waste disposal evaluation, and NEPA documents	Long-term performance analysis
Paul R. Nickens Battelle – Pacific Northwest National Laboratories	Ph.D., Anthropology, 1977 M.A., Anthropology, 1974 B.A., Anthropology, 1969	25 years – cultural resource management and Native American consultation	Cultural resources
Donna L. Osborne Jason Technologies Corporation	20 years experience	20 years – technical editing, document production and coordination; 2 years – NEPA documentation	Editor
W. Kent Ostler Jason Technologies Corporation	Ph.D., Plant Ecology, 1979 M.S., Botany, 1976 B.S., Botany, 1974	22 years – plant ecology and arid land reclamation; identification of techniques to mitigate human impacts on biotic communities; surveys and research on endangered and threatened species; mitigation strategies for recovery of species	Biological resources

Name	Education	Experience	Responsibility
Ted M. Poston Battelle – Pacific Northwest National Laboratories	M.S., Fisheries, 1978 B.A., Biology,1973	19 years – noise analysis; 26 years – environmental research and toxicology; 24 years – NEPA experience	Lead analyst, noise and ground vibration
Eugene M. Rollins Dade Moeller & Associates	M.S.P.H., Health Physics, 1976 B.S., Nuclear Engineering, 1973	25 years – technical and management experience in health physics and risk assessments related to the nuclear fuel cycle	Lead analyst, No-Action Alternative
Steven B. Ross Battelle Memorial Institute	M.S., Nuclear Engineering, 1987 B.S., Nuclear Engineering, 1985	16 years – safety analysis, risk assessment, transportation, regulatory analysis, and fire risk assessment	Transportation
Dillard B. Shipler Battelle Memorial Institute	M.S., Major in Physics, 1967 B.S., Major in Science & Math, 1957 Certified Health Physicist, 1983	40 years – environment, safety, and health protection; occupational health and safety; radiation protection; high-level waste management; risk assessment; regulatory compliance; NEPA; systems engineering; and project/program management.	Transportation; Comment-Response Document
Judith A. Shipman Jason Technologies Corporation	A.A., General Studies, 1991	26 years – NEPA documentation, document production coordination, editing	Production Coordinator, Editor; Comment-Response Document
Sandra Snyder Battelle Memorial Institute	M.S.P.H., Radiological Hygiene, 1991 B.S., Environmental Resource Management, 1986	10 years – assessment of environmental and occupational exposure to radionuclides and chemicals	Air quality
Dennis Strenge Battelle Memorial Institute	M.S., Chemical Engineering, 1968 B.S., Chemical Engineering	33 years – environment exposure analysis and dosimetry for accidental and chronic releases of radionuclides and chemicals	Accidents
Lucinda Low Swartz Battelle Memorial Institute	J.D., 1979 B.A., Political Science and Administrative Studies, 1976	21 years – environmental law and regulation, specializing in NEPA compliance	Summary

Name	Education	Experience	Responsibility
John E. von Reis Jason Technologies Corporation	J.D., 1969 B.A., English (Prelegal), 1966	28 years – energy, environmental, resource and regulatory issues	Lead analyst, purpose and need, regulatory requirements, mitigation, unavoidable adverse impacts, environmental justice
Dee H. Walker Jason Technologies Corporation	Ph.D., Chemical Engineering, 1963 M.S., Chemical Engineering, 1962 Oak Ridge School of Reactor Technology, 1954 B.S., Chemical Engineering, 1953	48 years – nuclear engineering; 11 years – effects of radiological releases on humans and the environment	Health and safety
Jeffrey L. Weiler Jason Technologies Corporation	M.S., Resource Economics/ Environmental Management, 1974 B.A., Political Science, 1970	28 years – management of large interdisciplinary project teams; interagency coordination; stakeholder involvement; NEPA compliance	Document Manager, Draft EIS; Comment-Response Document
Ruth Weiner Jason Technologies Corporation	Ph.D., Chemistry, 1962 M.S., Chemistry, 1959 M.S., Physics, 1957 B.S., Physics, 1956	14 years – risk assessment of airborne pollutants and transportation risks, decision analysis; 25 years – environmental impact assessment; 35 years – professor of chemistry and environmental studies; 15 years – radioactive waste disposal, radioactive waste policy and regulation	Transportation
Thomas J. Winnard Battelle Memorial Institute	B.S., Geology, 1984	12 years – information systems	Transportation

13.2 Reviewers

The DOE Yucca Mountain Project Office incorporated input into the preparation of this EIS from a number of other DOE offices that reviewed the document while it was under development. These included the Offices of Environmental Management, Naval Reactors, Nuclear Energy, Materials Disposition, the National Spent Fuel Program, and the National High-Level Waste Program. The DOE Yucca Mountain Site Characterization Office, Nevada Operations Office, Idaho National Engineering and Environmental Laboratory, Hanford Site, and Savannah River Site also participated in the reviews of this EIS. In addition, personnel on assignment to the Yucca Mountain Project Office from the U.S. Department of the Interior Bureau of Reclamation provided technical review and other support, as did personnel from the DOE Office of Civilian Radioactive Waste Management Technical Support Services Contractor (Booz-Allen & Hamilton and its subcontractors).

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR
PREPARATION OF THE
ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare and EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purpose of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

"Financial or other interest in the outcome of the project" includes "any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)". See 46 FR 18026-18031.

In accordance with these requirements, the offeror and the proposed subcontractors hereby certify as follows. (check either (a) or (b) and list financial or other interest if (b) is checked)

(a) ☑ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified By:

[signature]
Signature

James S. Holm
Name (Printed)

Director of Contracts
Title

Jason Associates Corporation
Company

June 7, 1999
Date

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5c, which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare an EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purposes of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

"Financial or other interest in the outcome of the project" includes "any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)". See 46 FR 18026-18031.

In accordance with these requirements, the offeror and the proposed subcontractors hereby certify as follows: (check either (a) or (b) and list financial or other interest if (b) is checked).

(a) ☑ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified by:

[signature]
Signature

Janet M. Mandel
Name (Printed)

Manager, Contract Operations
Title

Tetra Tech NUS, Inc.
Company

June 4, 1999
Date

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR
PREPARATION OF THE
ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare and EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purpose of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

"Financial or other interest in the outcome of the project" includes "any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)". See 46 FR 18026-18031.

In accordance with these requirements, the offeror and the proposed subcontractors hereby certify as follows. (check either (a) or (b) and list financial or other interest if (b) is checked)

(a) ☒ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified By: [signature]
Signature

RALPH K. HENRICKS
Name (Printed)

CONTRACTING OFFICER
Title

BATTELLE MEMORIAL INSTITUTE
COLUMBUS OPERATIONS
Company

June 7, 1999
Date

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR
PREPARATION OF THE
ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare and EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purpose of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

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(a) ☒ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified By:

[signature]
Signature

Matthew P. Moeller
Name (Printed)

Vice President
Title

Dade Moeller & Assoc.
Company

June 4, 1999
Date

14

Glossary

Main Index Vol 1 Index

14. GLOSSARY

(Note: A number of the terms in the Glossary emphasize their project-specific relationship to the Yucca Mountain Repository EIS. Words in *italics* refer to other words in the glossary.)

10,000-year peak of the mean annual dose

For this EIS, the largest annual *dose* analyzed within the first 10,000 years. See *peak of the mean annual dose (post-10,000 years)*.

100-year flood

A flood event of such magnitude that it occurs, on average, every 100 years; this equates to a 1-percent chance of its occurring in a given year.

500-year flood

A flood event of such magnitude that it occurs, on average, every 500 years; this equates to a 0.2-percent chance of its occurring in a given year.

A-weighted decibel scale

See *decibel, A-weighted*.

accessible environment

For this EIS, all points on Earth outside the surface and subsurface area controlled over the long term for the repository, including the atmosphere above the *controlled area*.

accident

An unplanned sequence of events that results in undesirable consequences. Examples in this EIS include an inadvertent release of *radioactive* or hazardous materials from their containers or *confinement* to the *environment*; vehicular accidents during the transportation of highly radioactive materials; and industrial accidents that could affect workers in the facilities.

acre-foot

The volume of water required to cover 1 acre to a depth of 1 foot (about 1,200 cubic meters or 330,000 gallons).

actinide

Any one of a series of chemically similar elements of *atomic numbers* 89 (actinium) through 103 (lawrencium). All actinides are *radioactive*.

active institutional control

Continued Federal control of the Yucca Mountain Repository site including access control, maintenance, monitoring, and surveillance of facilities and waste. See *institutional control*.

aerosol

A suspension of tiny, *colloid*-size particles or liquid droplets in air. Fog and smoke are common examples of aerosols.

affected environment

For an EIS, a description of the existing *environment* (that is, site description) covering information that relates directly to the scope of the *Proposed Action*, the *No-Action Alternative*, and the *implementing alternatives* being analyzed; in other words, the information necessary to assess or understand the *impacts*. This description must contain enough detail to support the impact analysis. The information must highlight "environmentally sensitive resources," if present; these include floodplains and wetlands, *threatened* and *endangered species*, prime and unique agricultural lands, and property of historic, archaeological, or architectural significance.

aging
: Retaining *commercial spent nuclear fuel* on the surface at the proposed repository for future emplacement in an underground *drift*. DOE could retain the spent nuclear fuel in either wet or dry storage. If the Department used dry storage, it would place the spent nuclear fuel in a storage module licensed by the Nuclear Regulatory Commission.

affected unit of local government
: The unit local government with jurisdiction over the site of a repository or a monitored retrievable storage facility. This term may, at the discretion of the Secretary of Energy, include units of local government that are contiguous with such unit. For the proposed, Yucca mountain Repository, the affected units of local government are Nye County, which has jurisdiction over the repository site and counties contiguous to Nye county (that is, Clark, Lincoln, White Pine, Eureka, Lander, Churchill, Mineral, and Esmeralda Counties in Nevada and Inyo County in California).

air lock
: A chamber or room in which air pressure can be regulated, usually between two regions of unequal pressure. The isolation air locks each consist of two *bulkheads* with doors that open and close in sequence.

air quality
: A measure of the concentrations of pollutants, measured individually, in the air.

ALARA
: See *as low as reasonably achievable.*

alcove
: A small excavation (room) off the main tunnel of a repository used for scientific study or for installing equipment.

alien species
: With respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem.

alignment
: As used in the transportation analysis in this EIS, the location of a rail line in a *corridor*.

alkali flat
: A level area or plain in an *arid* or semiarid region encrusted with alkali salts that become concentrated by evaporation and poor drainage. *Cap.* (Alkali Flat): An example of such terrain, approximately 25 miles south of the location in Amargosa Valley formerly known as Lathrop Wells along the Amargosa River.

alkalinity
: Acid-neutralizing capacity of a substance. High alkalinity conditions can promote metal *corrosion*.

Alloy-22

A *corrosion*-resistant, high-nickel alloy used for the outer shell of the *disposal container/waste package*, and for the parts of the emplacement pallet that would contact the waste package.

alluvial fan

A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream where it issues from a narrow mountain valley on a plain or broad valley.

alluvium

Sedimentary material deposited by flowing water.

alpha particle

A positively charged particle ejected spontaneously from the *nuclei* of some *radioactive* elements. It is identical to a helium nucleus and has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). See *ionizing radiation.*

alternate

As used in the transportation analysis in this EIS, a variation of a rail corridor segment to mitigate a potential adverse environmental or engineering factor. See *variation*, *option*, *corridor*.

alternative

One of two or more actions, processes, or propositions from which a *decisionmaker* will determine the course to be followed. The *National Environmental Policy Act*, as amended, states that in preparing an EIS, an agency "shall ... (s)tudy, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources" [42 U.S.C. 4321, Title I, Section 102 (E)]. The regulations of the Council on Environmental Quality that implement the National Environmental Policy Act indicate that the alternatives section in an EIS is "the heart of the environmental impact statement" (40 CFR 1502.14), and include rules for presenting the alternatives, including no action, and their estimated impacts.

This EIS has two alternatives: the *Proposed Action* under which DOE would construct, operate and monitor, and eventually close a *monitored geologic repository* for the *disposal* of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain, and the *No-Action Alternative* under which DOE would end *site characterization* activities at Yucca Mountain, and spent nuclear fuel and high-level radioactive waste at commercial storage sites and DOE facilities would continue to accumulate. The *Nuclear Waste Policy Act* states that this EIS does not have to discuss alternatives to geologic disposal or alternative sites to Yucca Mountain; DOE included the analysis of the No-Action Alternative to provide a basis for comparison with the Proposed Action. See *implementing alternative*.

DOE will base its decision on whether the repository program should proceed toward a site recommendation for Yucca Mountain in part on the Final EIS.

Amargosa Desert

The basin area lying south of Beatty, Nevada, and extending southeast some 80 kilometers (50 miles) to the area of Alkali Flat in California. The unincorporated Town of Amargosa Valley, Nevada, lies in the central portion of Amargosa Desert. Amargosa Desert is also the name of

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hydrographic area number 230 which is part of the Death Valley Groundwater Region; both are designations used by the State of Nevada in its water planning and appropriations efforts. The boundaries of the Amargosa Desert hydrographic area closely resemble those of the geographic area.

Amargosa River

The main drainage system of the *Amargosa Desert*. The Amargosa River drainage basin originates in the Pahute Mesa-Timber Mountain area north of Yucca Mountain and includes the main tributary systems of *Beatty Wash* and *Fortymile Wash*. The river, which is frequently dry along much of its length, flows southeastward through the Amargosa Desert and ends in the internal drainage system of Death Valley.

ambient

(1) Undisturbed, natural conditions such as ambient temperature caused by climate or natural *subsurface* thermal gradients. (2) Surrounding conditions.

ambient air

The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in the immediate proximity to emission sources.

ambient air quality standards

Standards established on a Federal or state level that define the limits for airborne concentrations of designated *criteria pollutants* [nitrogen dioxide, *sulfur dioxide*, *carbon monoxide*, *particulate matter* with aerodynamic diameters less than 10 microns (PM_{10}), *ozone*, and lead] to protect public health with an adequate margin of safety (primary standards) and to protect public welfare, including plant and animal life, visibility, and materials (secondary standards). See *criteria pollutants.*

analyzed land withdrawal area

See *land withdrawal area.*

aquifer

A *subsurface* saturated rock unit (formation, group of formations, or part of a formation) of sufficient *permeability* to transmit *groundwater* and yield usable quantities of water to wells and springs.

aquitard

A rock unit or layer or layer that stores water and allows it to move only at a very slow rate.

areal mass loading

As used in *thermal loading* calculations, the amount of *heavy metal* (usually expressed in metric tons of uranium or equivalent) emplaced per unit area in the proposed repository.

arid

(1) Areas where mean annual evaporation exceeds mean annual precipitation; (2) having insufficient rainfall to support agriculture; (3) the hyper-arid zone (arid index 0.03) comprises dryland areas without vegetation with the exception of a few scattered shrubs. Annual rainfall is low, rarely exceeding 100 millimeters (4 inches). In the arid zone (arid index 0.03-0.20), the native vegetation is sparse, being comprised of annual and perennial grasses and other herbaceous vegetation, and shrubs and small trees. There is high rainfall variability, with annual amounts ranging between 100 and 300 millimeters (4 and 12 inches).

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as low as reasonably achievable
: A process that applies a graded approach to reducing *dose* levels to workers and the public, and releases of *radioactive* materials to the *environment*. The goal of this process, often referred to as ALARA, is not merely to reduce doses, but to reduce them to levels that are as low are reasonable achievable.

assembly
: See *fuel assembly*.

atmospheric dispersion
: Movement of a *contaminant* as a result of the cumulative effect of the wind patterns and random motions of the air.

atomic mass
: The mass of a neutral atom, based on a relative scale, usually expressed in atomic mass units. See *atomic weight.*

atomic number
: The number of protons in an atom's nucleus.

atomic weight
: The relative mass of an atom based on a scale in which a specific carbon atom (carbon-12) is assigned a mass value of 12. Also known as relative *atomic mass*.

autolytic criticality
: A transient *criticality* in which the usual mechanisms that tend to shut down a criticality are delayed until a high *fission* rate is achieved.

backfill
: The general fill that is placed in the excavated areas of an underground facility. Backfill for the proposed repository could be *tuff* or other material.

background radiation
: *Radiation* from cosmic sources, naturally occurring *radioactive* materials such as granite, and global fallout from nuclear testing.

Bare Mountain
: An upfaulted mountain block that bounds the west side of *Crater Flat*.

barrier
: Any material, structure, or condition (as a thermal barrier) that prevents or substantially delays the movement of water or *radionuclides*. See *natural barrier*.

basalt
: A dark gray to black, dense to fine-grained *igneous* rock.

baseline
: Documentation of current conditions so that changes can be identified.

Beatty Wash

A tributary drainage to the *Amargosa River*; drains the west and north sides of the Yucca Mountain area.

berm

A mound or wall of earth.

beta particle

A negatively charged *electron* or positively charged positron emitted from a *nucleus* during decay. Beta decay usually refers to a radioactive transformation of a nuclide by electron emission, in which the atomic number increases by 1 and the mass number remains unchanged. In positron emission, the atomic number decreases by 1 and the mass number remains unchanged. See *ionizing radiation.*

biosphere

The ecosystem of the Earth and the living *organisms* inhabiting it.

blending

See *fuel blending.*

block-bounding fault

A high-angle, normal fault with relatively large displacement that bounds one or both sides of the fault-block mountains typical of the Basin and Range province.

boiling-water reactor (BWR)

A *nuclear reactor* that uses boiling water to produce steam to drive a turbine.

borehole

For this EIS, a hole drilled for purposes of collecting *site characterization* data or for supplying water.

borosilicate glass

High-level radioactive waste matrix material in which boron takes the place of the lime used in ordinary glass mixtures.

borrow areas

Areas outside the rail corridor where construction personnel could obtain materials to be used in the establishment of a stable platform (subgrade) for the rail track. Aggregate crushing operations could occur in these areas.

buffer cars

Railcars in front of or in back of those carrying *spent nuclear fuel* and *high-level radioactive waste* to provide additional distance to possibly occupied railcars or to railcars carrying hazardous materials other than *radioactive* materials. Federal regulations require the separation of a railcar carrying spent nuclear fuel and high-level radioactive waste from a locomotive, occupied caboose, carload of undeveloped film, or railcar carrying another class of hazardous material by at least one buffer car. These could be DOE railcars or, in the case of general freight service, commercial railcars.

bulkhead

A wall or embankment in a mine or tunnel that protects against earthslide, fire, water, or gas.

burnup

A measure of *nuclear reactor* fuel consumption expressed either as the percentage of fuel atoms that have undergone *fission* or as the amount of energy produced per unit weight of fuel.

caldera

An enlarged volcanic crater formed by explosion or collapse of the original crater.

cancer

A malignant tumor of potentially unlimited growth, capable of invading surrounding tissue or spreading to other parts of the body.

candidate species

Species for which the U.S. Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

canister

An unshielded metal container used as: (1) a pour mold in which molten vitrified *high-level radioactive waste* can solidify and cool; (2) the container in which DOE and electric utilities place intact *spent nuclear fuel*, loose rods, or nonfuel components for shipping or storage; or (3) in general, a container used to provide radionuclide *confinement*. Canisters are used in combination with specialized overpacks that provide structural support, shielding or confinement for storage, transportation, and *emplacement*. Overpacks used for transportation are usually referred to as transportation *casks*; those used for emplacement in a repository are referred to as *waste packages*.

capillary barrier

A contact in the *unsaturated zone* between a *geologic* unit containing relatively small-diameter openings and a unit containing relatively large-diameter openings across which water does not flow.

carbon monoxide

A colorless, odorless, poisonous gas produced by incomplete fossil-fuel combustion; one of the six pollutants for which there is a national *ambient air quality standard*.

carbon steel

A steel that is tough but malleable and contains a small percentage of carbon. The inner *barrier* of *waste packages* is composed of carbon steel.

carcinogen

An agent capable of producing or inducing *cancer*.

carcinogenic

Capable of producing or inducing *cancer*.

cask

(1) A heavily shielded container that meets applicable regulatory requirements used to ship *spent nuclear fuel* or *high-level radioactive waste*; (2) a heavily shielded container used by DOE and utilities for the *dry storage* of spent nuclear fuel; usable only for storage, not for transportation to or *emplacement* in a repository.

chain reaction

A process in which some of the *neutrons* released in one *fission* event cause other fission events that in turn release *neutrons*.

characterization

Activities in the laboratory or the field undertaken to establish the geologic conditions and the ranges of the parameters of a candidate site relevant to the location of a repository. These activities include borings, surface excavations, excavations of exploratory shafts, limited *subsurface* lateral excavations and borings, and *in situ* testing to evaluate the suitability of a candidate site for the location of a repository, but do not include preliminary borings and geophysical testing to assess if *site characterization* should be undertaken.

Civilian Radioactive Waste Management System

The organizational system of the DOE Office of Civilian Radioactive Waste Management; it is the composite of the sites and all facilities, systems, equipment, materials, information, activities, and personnel required to perform the activities necessary to manage *radioactive* waste *disposal*.

cladding

The metallic outer sheath of a fuel element generally made of stainless steel or a *zirconium alloy*. It is intended to isolate the fuel element from the external *environment*.

clastic

Describing a rock or sediment composed mainly of broken fragments of preexisting minerals or rocks that have been transported from their places of origin.

climate states

Representations of climate conditions. Six different climate states are used to represent changes in climate over the periods of interest: Interglacial Climate (the same as present-day), Glacial-Transition (also known as Intermedial Climate), Intermediate/Monsoon Climate, Glacial Climate Stage 8/10, Glacial Climate Stage 6/16, and Glacial Climate Stage 4.

closure

See *repository phases*.

co-disposal

A packaging method for *disposal* of *radioactive* waste in which two types of waste, such as *commercial spent nuclear fuel* and defense *high-level radioactive waste*, are combined in *disposal containers*. Co-disposal takes advantage of otherwise unused space in disposal containers and is more cost-effective than other methods to limit the reactivity of individual *waste packages*.

collective dose

See *population dose*.

colloid

Small particles in the size range of 10^{-9} to 10^{-6} meters that are suspended in a solvent. Naturally occurring colloids in *groundwater* arise from clay minerals.

colluvium

Loose earth material that has accumulated at the base of a hill, through the action of gravity.

commercial spent nuclear fuel

Commercial nuclear fuel rods that have been removed from *reactor* use. See *spent nuclear fuel* and *DOE spent nuclear fuel*.

conceptual model

A set of *qualitative* assumptions used to describe a system or subsystem for a given purpose. Assumptions for the model should be compatible with one another and fit the existing data within the context of the given purpose of the model.

confinement

As it pertains to *radioactivity*, the retention of *radioactive* material within some specified bounds. Confinement differs from containment in that there is no absolute physical *barrier* in the former.

construction

See *repository phases*.

construction/demolition debris

Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include materials such as soil, rock, masonry materials, and lumber.

construction support areas

Areas along the rail route that could be used as temporary residences for construction crews, material and equipment storage areas, and concrete production areas. Such camps probably would be for the construction of routes far from population centers.

contaminant

A substance that contaminates (pollutes) air, soil, or water. Also, a hazardous substance that does not occur naturally or that occurs at levels greater than those that occur naturally in the surrounding *environment*.

contaminant flux

Movement of a *contaminant* across a surface boundary per unit time (for example, *curies* per year; milligrams per year).

contamination

The intrusion of undesirable elements (unwanted physical, chemical, biological, or radiological substances, or matter that has an adverse effect) to air, water, or land.

controlled area

The area restricted for the long term for the repository, as identified by passive institutional controls DOE would install at *closure*. The controlled area is 300 square kilometers (about 120 square miles) maximum surface and subsurface area that extends in the predominant direction of groundwater flow no farther south than 36 degrees, 40 minutes, 13.6661 seconds north latitude (the present southwest corner of the Nevada Test Site), and no more than 5 kilometers (3 miles) from the repository footprint in any other direction. (See 40 CFR 197.12.)

convection
: (1) Thermally driven *groundwater* flow or a heat-transfer mechanism for a gas phase. The bulk motion of a flowing fluid (gas or liquid) in the presence of a gravitational field, caused by temperature differences that, in turn, cause different areas of the fluid to have different densities (for example, warmer is less dense). (2) One of the processes that moves solutes in *groundwater*.

corridor
: As used in the transportation analysis in this EIS, a strip of land, approximately 400 meters (0.25 mile) wide, that encompasses one of several possible routes through which DOE could build a branch rail line to transport *spent nuclear fuel*, *high-level radioactive waste,* and other material to and from the proposed Yucca Mountain Repository.

corrosion
: The process of dissolving or wearing away gradually, especially by chemical action.

corrosion-resistant material
: *Disposal container* material, such as Alloy-22, that oxidizes slowly in a corrosive environment.

cosmic radiation
: A variety of high-energy particles including protons that bombard the Earth from outer space. They are more intense at higher altitudes than at sea level where the Earth's atmosphere is most dense and provides the greatest protection.

cosmogenic radionuclides
: Radioactive nuclides generated when the upper atmosphere interacts with many of the cosmic radiations. Common cosmogenic radionuclides include carbon-14, tritium, and beryllium-7.

Crater Flat
: A north-trending, 6- to 11-kilometer (4- to 7-mile)-wide area west of Yucca Mountain; bounded by *Bare Mountain* on the west and Yucca Mountain on the east.

credible event/credible accident
: An event or *accident* scenario that the design of the *geologic repository* considers reasonably foreseeable with a possibility of at least 1 in 10 million.

criteria pollutants
: Six common pollutants (*ozone*, *carbon monoxide*, *particulates*, *sulfur dioxide*, lead, and nitrogen dioxide) known to be hazardous to human health and environment and for which the U.S. Environmental Protection Agency sets National Ambient Air Quality Standards under the Clean Air Act. See *toxic air pollutants*.

criticality
: The condition in which nuclear fuel sustains a *chain reaction*. It occurs when the number of neutrons present in one generation cycle equals the number generated in the previous cycle.

criticality control

Set of measures taken to maintain nuclear materials, including *spent nuclear fuel*, in a *subcritical* condition during storage, transportation, and *disposal*, so no self-sustaining nuclear *chain reaction* can occur. Subcriticality is maintained by loading spent nuclear fuel in specific configurations that meet requirements related to fuel age, enrichment, and reduction in nuclear fuel reactivity through *burnup*.

cross drift

An approximately 2,800-meter (9,200-foot)-long *drift* excavated to provide researchers new opportunities to study the geologic profile of the rock in the proposed repository area beneath Yucca Mountain. Researchers will conduct a new battery of tests in the cross drift as part of ongoing studies to determine if Yucca Mountain would be a suitable host for a deep *monitored geologic repository* for *spent nuclear fuel* and *high-level radioactive waste*. The cross drift begins inside the *Exploratory Studies Facility* approximately 2,000 meters (6,600 feet) from the northern entrance and cuts through the entire stratigraphic section of the potential Upper Block emplacement area.

crud

The *radionuclide* contribution from activated *corrosion* products deposited on the surfaces of *fuel assemblies* during reactor operations.

cumulative impact

The *impact* on the *environment* that results from the incremental impact(s) of an action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

curie

A unit of *radioactivity* equal to 37 billion *disintegrations* per second.

decay (radioactive)

The process in which one radionuclide spontaneously transforms into one or more different radionuclides called decay products.

decibel (dB)

A standard unit for measuring sound-pressure levels based on a reference sound pressure of 0.0002 dyne per square centimeter. This is the smallest sound a human can hear.

decibel, A-weighted (dBA)

A measurement of sound approximating the sensitivity of the human ear and used to characterize the intensity or loudness of sound.

decisionmaker

The group or individual responsible for making a decision on constructing and operating a *monitored geologic repository* for the disposal of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain.

decommissioning

The process of removing from service a facility in which nuclear materials are handled. It usually involves decontaminating the facility so that it may be dismantled or dedicated to other purposes.

decontamination

A process that removes, destroys, or neutralizes chemical, biological, or radiological contamination from a person, object, or area.

dedicated freight rail service

A train that handles only one commodity (in this case, *spent nuclear fuel* or *high-level radioactive waste*); this separate train with its own crew would limit switching between trains of the railcars carrying these materials.

defense-in-depth

(1) A design strategy based on a system of multiple, independent, and redundant *barriers*, designed to ensure that failure in any one barrier does not result in failure of the entire system. (2) The term used to describe a system of multiple barriers that mitigate *uncertainties* in conditions, processes, and events.

deformation

A change in the shape and size of a body.

design alternative

A fundamentally different conceptual design for a repository, which could stand alone as the License Application repository design concept.

design-basis event

Naturally or humanly induced events that are reasonably likely to occur one or more times before permanent closure of the *geologic repository's* operations area; in addition, any other natural or human-induced event that is unlikely, but is sufficiently credible to warrant consideration, taking into account the potential for significant radiological impacts on public health and safety.

design enhancement

An engineered *barrier* system feature that DOE is considering for possible inclusion in the design for the Yucca Mountain Repository. Design enhancements are not considered to be essential to the successful performance of the repository. The EIS analysis of the *Proposed Action* will not include design enhancements, but will identify them as possible means of *mitigation*. If a design enhancement is added to the reference design in time for inclusion in the EIS, it will be evaluated as part of the Proposed Action design.

deterministic

A single calculation using only a single value for each of the model parameters. A deterministic system is governed by definite rules of system behavior leading to cause and effect relationships and predictability. Deterministic calculations do not account for *uncertainty* in the physical relationships or parameter values.

dip-slip fault

A fault in which the relative displacement is along the direction of dip of the fault plane. If the block above the fault has moved downward it is a *normal fault*; upward movement indicates a *reverse fault*.

direct impact

Effect that results solely from the construction or operation of a proposed action without intermediate steps or processes. Examples include habitat destruction, soil disturbance, air emissions, and water use.

discretization

The process of dividing geometry into smaller pieces (finite elements) to prepare for analysis. For example, for the EIS analysis DOE divided the broad volume of the *unsaturated zone* beneath the proposed repository into smaller portions, each of which has its own set of characteristics, to model water flow and potential transport of *radionuclides* from the repository to the *saturated zone*.

disintegration

Any transformation of a *nucleus*, whether spontaneous or induced by *irradiation*, in which the nucleus emits one or more particles or *photons*.

disposable canister

A metal vessel for commercial or DOE *spent nuclear fuel* assemblies or solidified *high-level radioactive waste* with specialized overpacks to enable storage, transportation, and *emplacement* in a repository.

disposal

The *emplacement* in a repository of *high-level radioactive waste*, *spent nuclear fuel*, or other highly *radioactive* material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste, and the *isolation* of such waste from the *accessible environment*.

disposal container

The vessel consisting of the *barrier* materials and internal components in which the canistered or uncanistered waste form would be placed. The disposal container would include the container barriers or shells, spacing structures or baskets, shielding integral to the container, packing contained within the container, and other absorbent materials designed to be placed internal to the container or immediately surrounding the disposal container (that is, attached to the outer surface of the container). The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

disproportionately high and adverse environmental impacts

An environmental *impact* that is unacceptable or above generally accepted norms; these would include economic impacts of the *Proposed Action*. A disproportionately high impact is one (or the risk of one) to a *low-income population* or *minority population* that significantly exceeds the impact to the general population. In assessing cultural and aesthetic impacts, agencies consider impacts that would have unique effects on geographically dislocated or dispersed low-income or minority populations.

disproportionately high and adverse human health effects

Effects that occur when *impacts* to a *minority population* or *low-income population* from exposure to an environmental hazard significantly exceed the impacts to the general population and, where available, to an appropriate comparison group.

disruptive event

An unexpected event which, in the case of the repository, includes *human intrusion*, volcanic activity, *seismic* activity, and nuclear *criticality*. Disruptive events have two possible effects: (1) direct release of *radioactivity* to the surface, or (2) alteration of the expected behavior of the system.

dissolution

Molecular dispersion of a solid in a liquid.

distribution

As used in analyses of long-term performance, a range of values and probabilities associated with each value (or subrange of values) within the range. This can be in the form of a mathematical function or a table of values. *See normal distribution.*

DOE spent nuclear fuel

Radioactive waste created by defense activities that consists of more than 250 different waste forms. The major contributor to this waste form is the N-Reactor fuel currently stored at the Hanford Site. This waste form also includes 65 MTHM of *naval spent nuclear fuel*.

dose

The amount of radioactive energy taken into (absorbed by) living tissues.

dose equivalent

(1) The number (corrected for background) zero and above that is recorded as representing an individual's *dose* from external *radiation* sources or internally deposited *radioactive* materials; (2) the product of the absorbed dose in *rads* and a quality factor; (3) the product of the absorbed dose, the quality factor, and any other modifying factor. The dose equivalent quantity is used for comparing the biological effectiveness of different kinds of radiation (based on the quality of radiation and its spatial distribution in the body) on a common scale; it is expressed in *rem*.

dose rate

The *dose* per unit time.

dose risk

The product of a radiation dose and the probability of its occurrence.

drift

From mining terminology, a horizontal underground passage. Includes excavations for *emplacement* (emplacement drifts) and access (access mains).

drip shield

A corrosion-resistant engineered *barrier* that would be placed above the *waste package* to prevent seepage water from directly contacting the waste packages for thousands of years. The drip shield would also offer protection to the waste package from rockfall.

dry storage

Storage of *spent nuclear fuel* without immersing the fuel in water for cooling or shielding; it involves the encapsulation of spent fuel in a steel cylinder that might be in a concrete or massive steel *cask* or structure.

dual-purpose canister

A metal vessel suitable for storing (in a storage facility) and shipping (in a shipping cask) commercial *spent nuclear fuel* assemblies. At the repository, dual-purpose canisters would be removed from the shipping cask and opened. The *spent nuclear fuel* assemblies would be removed from the canister and placed in a *disposal container* or in the fuel pool to accomodate *blending*. The opened canister would be recycled or disposed of offsite as low-level *radioactive* waste.

earthquake

A series of elastic waves in the crust of the Earth caused by abrupt movement easing strains built up along *geologic* faults or by volcanic action and resulting in movement of the Earth's surface.

electron

A stable elementary particle that is the negatively charged constituent of ordinary matter.

emplacement

The placement and positioning of *waste packages* in the repository emplacement *drifts*.

endangered species

A species that is in danger of extinction throughout all or a significant part of its range; a formal listing of the U.S. Fish and Wildlife Service under the Endangered Species Act.

Energy Policy Act of 1992 (Public Law 102-486, 106 Stat. 2776)

Legislation that amends the *Nuclear Waste Policy Act* by directing (1) the Environmental Protection Agency to set site-specific public health and safety radiation protection standards from Yucca Mountain, and (2) the Nuclear Regulatory Commission to modify its technical requirements and licensing criteria to be consistent with the Environmental Protection Agency site-specific standards.

engineered barrier system

The designed, or engineered, components of the underground facility, including the *waste packages* and other engineered *barriers*.

enhanced design alternative

A combination (or variation) of one or more design alternatives and design features.

environment

(1) Includes water, air, and land and all plants and humans and other animals living therein, and the interrelationship existing among these. (2) The sum of all external conditions affecting the life, development, and survival of an *organism*.

environmental impact statement (EIS)

A detailed written statement which describes:

> "...the environmental impact of the proposed action; any adverse environmental effects which cannot be avoided should the proposal be implemented; alternatives to the proposed action (although the Nuclear Waste Policy Act, as amended, precludes consideration of certain alternatives); the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented."

Preparation of an EIS requires a public process that includes public meetings, reviews, and comments, as well as agency responses to the public comments.

environmental justice

The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

environmental monitoring

The process of sampling and analyzing environmental media in and around a facility to (1) confirm compliance with performance objectives and (2) detect *contamination* entering the *environment* to facilitate timely remedial action.

environmental resource areas

Areas examined for potential environmental impacts as part of the *National Environmental Policy Act* analysis process. Examples include air quality, hydrology, and biological resources.

ephemeral

Used in this EIS in reference to a nonpermanent stream or other body of water.

equilibrium

The state of a chemical system in which the phases do not undergo any spontaneous change in properties or proportions with time; a dynamic balance.

erionite

A natural fibrous *zeolite* in the rocks at Yucca Mountain that is listed as a known human carcinogen by recognized international agencies such as the International Agency for Research on Cancer.

escort cars

Railcars in which escort personnel would travel on trains carrying *spent nuclear fuel* or *high-level radioactive waste*.

evapotranspiration

The combined processes of evaporation and plant *transpiration* that remove water from the soil and return it to the air.

Exploratory Studies Facility

An underground laboratory at Yucca Mountain that includes an 8-kilometer (5-mile) main loop (tunnel), a 3-kilometer (2-mile) *cross drift*, and a research *alcove* system constructed for performing underground studies during *site characterization*. The data collected will contribute toward determining the suitability of the Yucca Mountain site as a repository. Some or all of the facility could be incorporated into the proposed repository.

exposure (to radiation)

The incidence of *radiation* on living or inanimate material by accident or intent. Background exposure is the exposure to natural *ionizing radiation*. Occupational exposure is the exposure to ionizing radiation that occurs during a person's working hours. Population exposure is the exposure to a number of persons who inhabit an area.

exposure pathway

The course a chemical or physical agent takes from the source to the exposed *organism*; describes a unique mechanism by which an individual or population can become exposed to chemical or physical agents at or originating from a release site. Each exposure pathway includes a source or a release from a source, an exposure point, and an exposure route.

far-field

The area of the geosphere and *biosphere* far enough away from the repository that, when numerically modeled, releases from the repository are represented as a homogeneous, single-source effect.

fault

A *fracture* or a fracture zone in crustal rocks along which there has been movement of the fracture's two sides relative to one another, so that what were once parts of one continuous rock stratum or vein are now separated.

Fiscal Year

A 12-month period to which a jurisdiction's annual budget applies and at the end of which its financial position and the results of its operations are determined. For example, the Fiscal Year for Clark and Nye Counties, the Cities of Las Vegas and North Las Vegas, the Towns of Tonopah and Pahrump, and the Clark County and Nye County School Districts runs from July 1 through the following June 30; the Federal Fiscal Year runs from October 1 through the following September 30.

fission

The splitting of a *nucleus* into at least two other nuclei, resulting in the release of two or three *neutrons* and a relatively large amount of energy.

fission products

Radioactive or nonradioactive atoms produced by the *fission* of heavy atoms, such as uranium.

flexible design

As used in this EIS, the repository design and operating modes presented in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration*. See *higher-temperature repository operating mode* and *lower-temperature repository operating mode*.

floodplain

The lowlands adjoining inland and coastal waters and relatively flat areas and floodprone areas of offshore islands including, at a minimum, that area inundated by a 1 percent or greater chance flood in any given year. The base floodplain is defined as the 100-year (1.0-percent) floodplain. The critical action floodplain is defined as the 500-year (0.2-percent) floodplain.

Fortymile Wash

A major tributary to the *Amargosa River*; drains *Jackass Flats* to the east of Yucca Mountain; usually dry along most of its length.

fracture

A general term for any break in a rock, whether or not it causes displacement, caused by mechanical failure from stress. Fractures include cracks, joints, and *faults*. Fractures can act as pathways for rapid *groundwater* movement.

fuel assembly

A number of fuel elements held together by structural materials, used in a *nuclear reactor*. Sometimes called a fuel bundle.

fuel blending

The process of loading low-heat-output waste with high-heat-output waste in a *waste package* to balance its total heat output. This process would apply only to *commercial spent nuclear fuel*.

fugitive dust

Particulate matter composed of soil; can include emissions from haul roads, wind erosion of exposed soil surfaces, and other activities in which soil is removed or redistributed.

fugitive emissions

Emissions released directly into the *atmosphere* that could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

GENII

A *deterministic* computer software code that evaluates *dose* from the migration of radionuclides introduced into the *accessible environment*, or *biosphere*, that may eventually affect humans through ingestion, inhalation, or direct *radiation*. It is used to develop biosphere dose conversion factors.

gamma ray

The most penetrating type of radiant nuclear energy. It does not contain particles and can be stopped by dense materials such as concrete or lead. *See ionizing radiation.*

general freight rail service

Railroad line service that uses trains that move railcars, each of which might contain a different commodity. Railcars carrying *spent nuclear fuel* or *high-level radioactive waste* could be switched (in railyards or on sidings) successively from one general freight train to another as they traveled from the commercial and DOE locations to Nevada.

geologic

Of or related to a natural process acting as a dynamic physical force on the Earth (faulting, erosion, mountain building resulting in rock formations, etc.).

geologic repository

A system for disposing of *radioactive* waste in excavated *geologic* media, including surface and *subsurface* areas of operation, and the adjacent part of the geologic setting that provides *isolation* of the radioactive waste in the *controlled area*.

Great Basin

A subprovince of the Basin and Range province, generally characterized by north-trending mountain ranges and intervening basins, stretching from eastern Oregon to southern California.

Greater-Than-Class-C waste

Low-level nuclear waste generated by the commercial sector that exceeds U.S. Nuclear Regulatory Commission concentration limits for Class-C low-level waste, as specified in 10 CFR Part 61. DOE is responsible for disposing of this type of waste from its nondefense programs.

Gross Regional Product

The dollar value of all final goods and services produced in a given year in a specific region (such as the *region of influence*).

ground support

The system (rock bolts with wire mesh, steel structures, cast or precast concrete sections) used to line the main and emplacement *drifts* to minimize rock or earth falling into the drifts.

ground vibration

The rapid linear motion of a compression wave in the ground caused by a single or repeated force or impact to the ground as in the action of a pile driver or a tire hitting a bump or pothole in a road.

groundwater

Water contained in pores or fractures in either the *unsaturated zone* or *saturated zone* below ground level.

habitat

Area in which a plant or animal lives and reproduces.

half-life (radiological)

The time in which half the atoms of a *radioactive* substance decay to another nuclear form. Half-lives range from millionths of a second to billions of years depending on the stability of the nuclei.

hazardous chemical

As defined under the Occupational Safety and Health Act and the Community Right-to-Know Act, a chemical that is a physical or health hazard.

hazardous pollutant

Hazardous chemical that can cause serious health and environmental hazards, and listed on the Federal list of hazardous air pollutants (42 U.S.C. 7412). See *toxic air pollutants*.

hazardous waste

Waste designated as hazardous by Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents. (Note: The proposed Yucca Mountain Repository would not accept hazardous waste, either solid or liquid, and DOE would dispose of all repository-generated hazardous waste at offsite facilities.)

heavy-haul truck

An overweight, overdimension vehicle that must have permits from state highway authorities to use public highways; a vehicle DOE would use on public highways to move *spent nuclear fuel* or *high-level radioactive waste shipping casks* designed for a railcar.

heavy metal

All uranium, plutonium, and thorium used or generated in a manmade *nuclear reactor*.

high-efficiency particulate air filter

A filter with an efficiency of at least 99.95 percent that separates particles from an air exhaust stream before the air is released to the atmosphere.

higher-temperature repository operating mode

The *flexible design* would maintain the repository host rock temperatures below the boiling point of water [96°C (205°F) at the elevation of the repository] during the preclosure period with continuous ventilation of the *emplacement drifts*. After mechanical ventilation was discontinued at closure, host rock temperatures would increase above the boiling point of water, and moisture around the emplacement drifts would evaporate and be driven away from the drifts as water vapor. A boiling zone would develop around each emplacement drift, but it would not extend all the way across the *pillars*. This mode would allow percolation of moisture downward past the *emplacement horizon* through central portions of the rock pillars between the drifts. See *lower-temperature repository operating mode.*

high-level radioactive waste

(1) The highly *radioactive* material that resulted from the reprocessing of *spent nuclear fuel*, including liquid waste produced directly in reprocessing, and any solid material derived from such liquid waste that contains *fission* products in sufficient concentrations. (NOTE: DOE would vitrify liquid *high-level radioactive waste* before shipping it to the repository.) (2) Other highly radioactive material that the Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent *isolation*.

Highway Route-Controlled Quantities of Radioactive Material

Thresholds for certain quantities of *radioactive* materials above which shipments are subject to specific routing controls that apply to the highway carrier. These thresholds are defined by U.S. Department of Transportation regulations (49 CFR Part 177). (49 CFR Part 397 Subpart D defines routing requirements.)

horizon

See *repository horizon*.

human intrusion

The inadvertent disturbance of a *disposal* system by the activities of humans that could result in release of *radioactive* waste. 40 CFR Part 191 Subpart B requires that *performance assessments* consider the possibility of human intrusion.

hydrogeology

A study that encompasses the interrelationships of *geologic* materials and processes involving water.

hydrographic area

In reference to Nevada *groundwater*, divisions of the State into groundwater basins and sub-basins based primarily on topographic features such as mountains and valleys. The State uses the map of hydrographic areas as the basis for water planning, management, and administration. (Because they are based heavily on topographic features, hydrographic area boundaries sometimes differ from groundwater basin designations developed from studies of inferred or measured groundwater flow patterns.)

hydrology

(1) The study of water characteristics, especially the movement of water. (2) The study of water, involving aspects of geology, oceanography, and meteorology.

igneous

(1) A type of rock formed from a molten, or partially molten, material. (2) An activity related to the formation and movement of molten rock either in the *subsurface* (plutonic) or on the surface (volcanic).

impact

For an EIS, the positive or negative effect of an action (past, present, or future) on the natural *environment* (land use, air quality, water resources, geological resources, ecological resources, aesthetic and scenic resources) and the human environment (infrastructure, economics, social, and cultural).

impact limiters

Devices attached to rail and truck *shipping casks* that would help absorb impact energy in the event of a collision.

implementing alternative

An action or proposition by DOE necessary to implement the *Proposed Action* and to enable the estimation of the range of reasonably foreseeable *impacts* of that action or proposition.

- The implementing rail/intermodal alternatives for Nevada transportation are the five corridors for a new rail spur:
  - Caliente
  - Carlin
  - Caliente-Chalk Mountain
  - Jean
  - Valley Modified

- The five *intermodal transfer station*/heavy-haul route combinations:
  - Caliente intermodal transfer station, Caliente route
  - Caliente intermodal transfer station, Caliente-Chalk Mountain route
  - Caliente intermodal transfer station, Caliente-Las Vegas route
  - Sloan/Jean intermodal transfer station, Sloan/Jean route
  - Apex/Dry Lake intermodal transfer station, Apex/Dry Lake route

DOE decisions on implementing alternatives will be made when they are ripe for decisionmaking, which might occur after a decision to construct and operate the Yucca Mountain Repository.

inadvertent intrusion
: The unintended disturbance of a *disposal* facility or its immediate *environment* by a future occupant that could result in a loss of *containment* of the waste or *exposure* of people.

incident-free transportation
: Routine transportation in which cargo travels from origin to destination without being involved in an *accident*.

indirect impact
: An effect that is related to but removed from a proposed action by an intermediate step or process. Examples include surface-water quality changes resulting from soil erosion at construction sites, and reductions in productivity resulting from changes in soil temperature.

industrial wastewater
: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression and process water from building heating, ventilation, and air conditioning systems.

inert
: Lacking active thermal, chemical, or biological properties. An inert atmosphere is incapable of supporting combustion.

infiltration
: The process of water entering the soil at the ground surface and the ensuing movement downward. Infiltration becomes *percolation* when water has moved below the depth at which it can return to the atmosphere by evaporation or *evapotranspiration*.

infrastructure
: Basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communication systems. These include surface and *subsurface* facilities (for example, service drifts, transporters, electric power supplies, waste handling buildings, administrative facilities).

in situ
: In its natural position or place. The phrase distinguishes in-place experiments, conducted in the field or underground facility, from those conducted in the laboratory.

institutional control
: Monitoring and maintenance of storage facilities to ensure that radiological releases to the *environment* and *radiation* doses to workers and the public remain within Federal limits and DOE

Order requirements. *Active institutional control* would require the presence of humans to safeguard and maintain the site; passive institutional control would include such devices as permanent markers and land records to warn future generations of dangers.

intermodal transfer station

A facility at the juncture of rail and road transportation used to transfer *shipping casks* containing *spent nuclear fuel* and *high-level radioactive waste* from rail to truck and empty casks from truck to rail.

intermodal transfer station candidate area

Area near one or more existing main rail lines that DOE is considering for the location of an *intermodal transfer station*.

intrablock fault

A relatively minor fault that lies between the major north-trending, block-bounding faults. Also called subsidiary fault.

intrusive sound

A new sound that, either because of its loudness in relation to the local *ambient* sound level, or because of such characteristics as tone content, impulsive or unexpected nature, or high information content, is annoying or detracts from the usual ambiance of the receptor location. See *noise*.

invasive species

An *alien species* whose introduction does or is likely to cause economic or environmental harm or harm to human health.

invert

The structure constructed in a *drift* to provide the floor of that drift. In an *emplacement* drift, ballast in the invert would serve as a *barrier* to migration of *radionuclides* that escaped from breached *waste packages*.

involved worker

A worker who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, and *emplacement* of waste materials; and *monitoring* of the condition and performance of the *waste packages*. See *noninvolved worker*.

ion

(1) An atom that contains excess *electrons* or is deficient in electrons, causing it to be chemically active. (2) An electron not associated with a *nucleus*.

ionizing radiation

(1) *Alpha particles*, *beta particles*, *gamma rays*, *X-rays*, *neutrons*, high-speed *electrons*, high-speed *protons*, and other particles capable of producing *ions*. (2) Any radiation capable of displacing electrons from an atom or molecule, thereby producing ions.

irradiation

Exposure to *radiation*.

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isolation

Inhibiting the transport of *radioactive* material so that the amounts and concentrations of this material entering the *accessible environment* stay within prescribed limits.

isotope

One of two or more atomic *nuclei* with the same number of *protons* (that is, the same *atomic number*) but with a different number of *neutrons* (that is, a different *atomic weight*). For example, uranium-235 and uranium-238 are both isotopes of uranium.

Jackass Flats

A broad asymmetric basin 8 to 10 kilometers (5 to 6 miles) wide and 20 kilometers (12 miles) long that is east of Yucca Mountain and is drained by *Fortymile Wash*.

juvenile failure

Premature failure of a *waste package* because of material imperfections or damage by rockfall during *emplacement*.

land withdrawal area

An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Las Vegas Valley shear zone

A major right-lateral strike-slip zone of faulting.

latent cancer fatality

A death resulting from *cancer* that has been caused by exposure to *ionizing radiation*. For exposures that result in cancers, the generally accepted assumption is that there is a latent period between the time an exposure occurs and the time a cancer becomes active.

legal-weight truck

A truck with a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be within Federal and state regulations.

License Application

An application to the Nuclear Regulatory Commission to construct a *geologic repository* for the disposal of *spent nuclear fuel* and *high-level radioactive waste*. The application would be considered by the Nuclear Regulatory Commission in any decision whether to grant DOE authorization to begin constructing a repository.

line-loading repository design

A waste *emplacement* design in which *waste packages* would be spaced closely enough along the axis of the *drift* such that the heat source could be assumed to be continuous in long-term performance analyses.

linear thermal load

Heat output per unit length of the emplacement *drift*; expressed in kilowatts per meter.

lithology

The study and description of the general, gross physical characteristics of a rock, especially sedimentary *clastics*, including color, grain size, and composition.

lost workday cases

Incidents that result in injuries that cause the loss of work time.

lower-temperature repository operating mode

The *flexible design* would have the ability to hold repository host rock temperatures below the boiling point of water [96°C (205°F) at the elevation of the repository] after closure by a combination of methods such as increasing the continuous ventilation period, aging the fuel prior to *emplacement*, and increasing the spacing between emplaced waste packages. The mode ranges include conditions under which the drift rock wall temperatures would be below the boiling point of water, and conditions under which the waste package surface temperature would not exceed 85ºC (185ºF). To bound the impact analysis, DOE considered conditions under which the rock wall temperatures would be above the boiling point of water, and conditions under which waste package surface temperatures would not exceed 85ºC. See *higher-temperature repository operating mode*.

low-income population

One in which 20 percent or more of the persons in the population live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements.

low-level radioactive waste

Radioactive waste that is not classified as *high-level radioactive waste*, *transuranic waste*, or byproduct tailings containing uranium or thorium from processed ore. Usually generated by hospitals, research laboratories, and certain industries.

maintenance

Activities during the repository operation and monitoring phase including maintenance of *subsurface* monitoring and instrumentation systems and utilities (compressed air, water supply, fire water, wastewater system, power supply, and lights), maintenance of the main ventilation fan installations and surface facilities related to underground activities, and site security. Maintenance also preserves the capability to retrieve emplaced *waste packages*. See *repository phases*.

matrix (geology)

The solid, but porous, portion of rock.

maximally exposed individual

A hypothetical individual whose location and habits result in the highest total radiological or chemical exposure (and thus *dose*) from a particular source for all exposure routes (for example, inhalation, ingestion, direct exposure). The EIS analyses used the concept of the maximally exposed individual to evaluate potential short-term impacts to individuals around the repository and from transportation (and for some aspects of the *No-Action Alternative*). The EIS analyses used the concept of the maximally exposed individual to evaluate potential short-term impacts to individuals around the repository and from transportation (and for some aspects of the No-Action Alternative. For potential impacts to individuals from long-term repository performance, see *receptor*.

Maximum Contaminant Level

Under the Safe Drinking Water Act, the maximum permissible concentrations of specific constituents in drinking water that is delivered to any user of a public water system that serves 15 or more connections and 25 or more people; the standards established as maximum contaminant levels consider the feasibility and cost of attaining the standard.

maximum reasonably foreseeable accident

An accident characterized by extremes of mechanical (impact) forces, heat (fire), and other conditions that would lead to the highest foreseeable consequences. In general, accidents with conditions that have a chance of occurring more often than 1 in 10 million in a year are considered to be reasonably foreseeable.

metamorphic

Rock in which the original mineralogy, texture, or composition has changed due to the effects of pressure, temperature, or the gain or loss of chemical components.

metric tons of heavy metal (MTHM)

Quantities of *spent nuclear fuel* without the inclusion of other materials such as *cladding* (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume.

millirad

One one-thousandth (0.001) of a *rad*.

millirem

One one-thousandth (0.001) of a *rem*.

minority population

A community in which the percent of the population of a racial or ethnic minority is 10 points higher than the percent found in the population as a whole.

mitigation

Actions and decisions that (1) avoid *impacts* altogether by not taking a certain action or parts of an action, (2) minimize impacts by limiting the degree or magnitude of an action, (3) rectify the impact by repairing, rehabilitating, or restoring the *affected environment*, (4) reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action, or (5) compensate for an impact by replacing or providing substitute resources or *environments*.

mixed-oxide fuel

A mixture of uranium oxide and plutonium oxide that could be used to power commercial nuclear reactors.

monitored geologic repository

A system, requiring licensing by the U.S. Nuclear Regulatory Commission, intended or used for the permanent underground *disposal* of *radioactive* waste (including *spent nuclear fuel*). A *geologic repository* includes (1) the geologic repository operations area, and (2) the geologic setting in the *controlled area* that provides *isolation* of the radioactive waste. The repository would be monitored between *emplacement* of the last *waste package* and closure.

monitoring

Activities during the repository operation and monitoring phase including the surveillance and testing of *waste packages* and the repository for *performance confirmation*. See *repository phases*.

National Environmental Policy Act, as amended (NEPA; 42 U.S.C. 4321 *et seq.*)

The Federal statute that is the national charter for protection of the *environment*. The Act is implemented by procedures issued by the Council on Environmental Quality and DOE.

native species

With respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem.

natural barrier

The physical components of the geologic *environment* that individually and collectively act to limit the movement of water or radionuclides. See *barrier*.

natural system

A host rock suitable for repository construction and waste *emplacement* and the surrounding rock formations. It includes *natural barriers* that provide *containment* and *isolation* by limiting radionuclide transport through the geohydrologic *environment* to the *biosphere* and provide conditions that will minimize the potential for *human intrusion* in the future.

natural ventilation

Ventilation driven by a difference in density between the air columns in connected *shafts* or ramps. The density difference is generally caused by a difference in air temperature between the shafts, which results in a pressure differential that induces the air flow. This phenomenon, which is common in underground mines, can be enhanced by differences in elevation between the intake and exhaust locations. In relation to this EIS, the repository would be unique in that, due to the heat output of the emplaced waste, the exhaust air temperature would virtually always be higher than the intake temperature. The heat supplied by the waste and the difference in elevation between the intake and exhaust shaft portals would mean that there would always be a pressure differential, and that it would always be positive (that is, it would induce flow from the intakes to the exhausts).

naval spent nuclear fuel

Spent nuclear fuel discharged from reactors in surface ships, submarines, and training reactors operated by the U.S. Navy.

near-field

The area of and conditions in the repository including the *drifts* and *waste packages* and the rock immediately surrounding the drifts. The region around the repository where the natural hydrogeologic system would be significantly impacted by the excavation of the repository and the *emplacement* of waste.

neutron

An atomic particle with no charge and an atomic mass of 1; a component of all atoms except hydrogen; frequently released as *radiation*.

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neutron absorber

A material (such as boron or gadolinium) that absorbs neutrons. Used in *nuclear reactors*, transportation *casks*, and *waste packages* to control neutron activity and prevent criticality.

nitrogen oxides

Gases formed in great part from atmospheric nitrogen and oxygen when combustion occurs under conditions of high temperature and high pressure; a major air pollutant. Two primary nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2), are important airborne *contaminants*. Nitric oxide combines with atmospheric oxygen to produce nitrogen dioxide. Both nitric oxide and nitrogen dioxide can, in high concentration, cause lung cancer. Nitrogen dioxide is a *criteria pollutant*.

No-Action Alternative

The *Nuclear Waste Policy Act* states that this EIS does not have to discuss *alternatives* to geologic disposal or alternative sites to Yucca Mountain; DOE included the analysis of the No-Action Alternative to provide a basis for comparison with the *Proposed Action*. For this EIS, under the No-Action Alternative DOE would end *site characterization* activities at Yucca Mountain and continue to accumulate *spent nuclear fuel* and *high-level radioactive waste* at commercial storage sites and DOE facilities. See *alternative*.

noble gas

Any of a group of rare gases that include helium, neon, argon, krypton, xenon, and radon and that exhibit great chemical stability and extremely low reaction rates; also called *inert* gas. Xenon and radon exhibit extremely low reaction rates.

noise

Any sound that is undesirable because it interferes with speech and hearing; if intense enough, it can damage hearing.

nominal scenario

Long-term performance of the proposed repository using the Proposed Action modeled inventory, undisturbed by volcanic activity or human intrusion, but including seismic activity.

nonattainment area

An area that does not meet the *ambient air quality standard* for one or more criteria pollutants. Further designations (for example, serious, moderate) describe the magnitude of the nonattainment.

noninvolved worker

A worker who would perform managerial, technical, supervisory, or administrative activities but would not be directly involved in construction, excavation, or operations activities. See *involved worker*.

normal distribution

As used in analyses of long-term performance, a special type of symmetrical distribution known in the science of statistics as the Gaussian Distribution and commonly known as the "bell-shaped curve." *See distribution.*

normal fault

A fault in which the relative displacement is along the direction of dip of the fault plane (*dip-slip fault*) where the block above the fault has moved downward in relation to the block below the fault. See *reverse fault*.

nuclear radiation

Radiation that emanates from an unstable atomic *nucleus*.

nuclear reactor

A device in which a nuclear *fission chain reaction* can be initiated, sustained, and controlled to generate heat or to produce useful radiation.

nuclear waste

Unusable by-products of nuclear power generation, nuclear weapons production, and research, including *spent nuclear fuel, high-level radioactive waste*.

Nuclear Waste Policy Act (NWPA; 42 U.S.C. 10101 *et seq.*)

The Federal statute, originally enacted in 1982 (Public Law 97-425; 96 Stat. 2201), that established the Office of Civilian Radioactive Waste Management and defines its mission to develop a Federal system for the management and geologic disposal of *commercial spent nuclear fuel* and other *high-level radioactive wastes*, as appropriate. The Act also specifies other Federal responsibilities for nuclear waste management, establishes the Nuclear Waste Fund to cover the cost of geologic *disposal*, authorizes interim storage under certain circumstances, and defines interactions between Federal agencies and the states, local governments, and Native American tribes. The Act was substantially amended in 1987 (see *Nuclear Waste Policy Act Amendments of 1987*) and 1992 (see *Energy Policy Act of 1992*).

Nuclear Waste Policy Act Amendments of 1987 (Public Law 100-203; 101 Stat. 1330)

Legislation that amended the *Nuclear Waste Policy Act* to limit repository *site characterization* activities to Yucca Mountain, Nevada; establish the Office of Nuclear Waste Negotiator to seek a state or Native American tribe willing to host a repository or monitored retrievable storage facility; create the *Nuclear Waste Technical Review Board*; and increase state and local government participation in the waste management program.

Nuclear Waste Technical Review Board

An independent body established within the executive branch, created by the *Nuclear Waste Policy Amendments Act of 1987* to evaluate the technical and scientific validity of activities undertaken by the U.S. Department of Energy, including *site characterization* activities and activities relating to the packaging or transportation of *high-level radioactive waste* or *spent nuclear fuel*. Members of this Board are appointed by the President from a list prepared by the National Academy of Sciences.

nucleus

The central, positively charged, dense portion of an atom. Also known as atomic nucleus.

nuclide

An atomic *nucleus* specified by its *atomic weight*, *atomic number*, and energy state; a radionuclide is a *radioactive* nuclide.

oblique-slip fault

A *fault* that combines some purely horizontal motion (*strike-slip fault*) with some along the direction of the dip of the fault plane (*dip-slip fault*).

offsite

Physically not in a repository-related area managed by DOE.

onsite

Physically in an area managed by DOE where access can be limited for any reason. The site boundary encompasses *controlled areas*. The site comprises the various Operations Areas and the areas between and immediately surrounding them.

operational storage

A storage capacity DOE could use to collect material shipped to the repository before (or after) its insertion in *waste packages* and *emplacement* in the repository.

operation and monitoring

See *repository phases*.

option

As used in the transportation analysis in this EIS, a variation based on a determination that the location of a rail *corridor* segment is essentially equivalent to that of another option considering environmental and engineering factors. See *variation*, *alternate*, *corridor*.

organism

An individual constituted to carry on the activities of life by means of organs separate but mutually dependent; a living being.

overburden

Geologic material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials. As used by the Yucca Mountain Project, this is geologic material overlying the *repository block*.

overweight, overdimension truck

Semi- and tandem tractor-trailer trucks with gross weights over 80,000 pounds that must obtain permits from state highway authorities to use public highways.

ozone (O_3)

The triatomic form of oxygen; in the *stratosphere*, ozone protects the Earth from the Sun's *ultraviolet radiation*, but in lower levels of the atmosphere it is an air pollutant.

Paleozoic Era

A geologic era extending from the end of the Precambrian to the beginning of the Mesozoic, dating from about 600 to 230 million years ago.

particulate matter

Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions. See PM_{10}.

pathway

A potential route by which radionuclides might reach the *accessible environment* and pose a threat to humans.

peak of the mean annual dose (post-10,000 years)

For this EIS, the maximum of the mean annual *dose* analyzed for the 1-million-year postclosure period. Because the dose would decline after this peak, this would be the peak for all time after closure. See *10,000-year peak of the mean annual dose*.

pediment

A planar sloping rock surface forming a ramp to a front of a mountain range in an arid region. It might be covered locally by a thin *alluvium*.

perched water

A *saturated zone* condition that is not continuous with the *water table*, because there is an impervious or semipervious layer underlying the perched zone or a *fault* zone that creates a *barrier* to water movement and perches water. See *permeable*.

percolation

The passage of a liquid through a porous substance. In rock or soil it is the movement of water through the interstices and pores under hydrostatic pressure and the influence of gravity. The downward or lateral flow of water that becomes net *infiltration* in the *unsaturated zone*.

perennial yield

The amount of usable water from a *groundwater* aquifer that can be economically withdrawn and consumed each year for an indefinite period. It cannot exceed the natural recharge to that aquifer and ultimately is limited to the maximum amount of discharge that can be used for beneficial use.

performance assessment

An analysis that estimates the potential behavior of a system or system component under a given set of conditions. Performance assessments include estimates of the effects of *uncertainties* in data and modeling. See *Total System Performance Assessment.*

performance confirmation

The program of tests, experiments, and analyses conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after *permanent closure* will be met.

permanent closure

Final sealing of *shafts* and *boreholes* of the underground facility, including the installation of permanent monuments to mark the location and boundaries of the repository.

permeable

Pervious; a permeable rock is a rock, either porous or cracked, that allows water to soak into and pass through it freely.

permeability

In general terms, the capacity of such mediums as rock, sediment, and soil to transmit liquid or gas. Permeability depends on the substance transmitted (oil, air, water, etc.) and on the size and shape of the pores, joints, and fractures in the medium and the manner in which they interconnect. “Hydraulic conductivity” is equivalent to “permeability” in technical discussions relating to *groundwater*.

person-rem
A unit used to measure the *radiation* exposure to an entire group and to compare the effects of different amounts of radiation on groups of people; it is the product of the average *dose equivalent* (in *rem*) to a given organ or tissue multiplied by the number of persons in the population of interest.

pH
A number indicating the acidity or alkalinity of a solution. A pH of 7 indicates a neutral solution. Lower pH values indicate more acidic solutions while higher pH values indicate alkaline solutions.

photon
A massless particle, the quantum of an electromagnetic field, carrying energy, momentum, and angular momentum.

photovoltaic
Capable of generating a voltage as a result of exposure to *radiation*. Solar power generation systems use photovoltaic energy from the sun’s radiation to produce electricity.

picocurie
One one-trillionth (1×10^{-12}) of a *curie*.

pillar
The rock section between adjacent *emplacement drifts*.

PM_{10}
All *particulate matter* in the air with an aerodynamic diameter less than or equal to a nominal 10 micrometers (0.0004 inch). Particles less than this diameter are small enough to be breathable and could be deposited in lungs.

polycyclic volcanism
Multiple cycles of volcanic activity, as in describing a cinder cone that resulted from numerous volcanic events separated by significant intervals of time (as opposed to a cone generated by a single event or a tightly grouped series of events).

population dose
A summation of the radiation doses received by individuals in an exposed population; equivalent to *collective dose*; expressed in *person-rem*.

portal
Surface entrance to a mine, particularly in a *drift* or tunnel. The North and South Portals are the two primary entrances to the *subsurface* facilities.

postclosure controlled area
See *controlled area*.

preferred route

A public highway route that satisfies the requirements of U.S. Department of Transportation regulations (49 CFR Part 397, Subpart D) to be acceptable for shipments of *Highway Route-Controlled Quantities of Radioactive Material*.

pressurized-water reactor (PWR)

A nuclear power *reactor* that uses water under pressure as a coolant. The water boiled to generate steam is in a separate system.

prime farmland

Land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor, and without intolerable soil erosion.

probabilistic

(1) Based on or subject to *probability*. (2) Involving a variable factor, such as temperature or porosity. At each instance of time, the factor may take on any of the values of a specified set with a certain probability. Data from a probabilistic process is an ordered set of observations, each of which is one item in a probability distribution.

probability

The relative frequency at which an event can occur in a defined period. Statistical probability is about what actually happens in the real world and can be verified by observation or sampling. Knowing the exact probability of an event is usually limited by the inability to know, or compile the complete set of, all possible outcomes over time or space. Probability is measured on a scale of 0 (event will *not* occur) to 1 (event *will* occur).

probable maximum flood

The hypothetical flood (peak discharge, volume, and hydrographic shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of probable maximum precipitation and other hydrologic factors, such as sequential storms and snowmelts, that are favorable for maximum flood runoff.

proposed action

The activity proposed to accomplish a Federal agency's purpose and need. An EIS analyzes the environmental *impacts* of the Proposed Action. A proposed action includes the project and its related support activities (preconstruction, construction, and operation, along with postoperational requirements). The Proposed Action in this EIS is the construction, operation and monitoring, and eventual closure of a *monitored geologic repository* for *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain in Nevada (see *repository phases*).

proton

An elementary particle that is the positively charged component of ordinary matter and, together with the *neutron*, is a building block of all atomic *nuclei*.

pyroclastic

Of or relating to individual particles or fragments of *clastic* rock material of any size formed by volcanic explosion or ejected from a volcanic vent.

qualitative

With regard to a variable, a parameter, or data, an expression or description of an aspect in terms of non-numeric qualities or attributes. See *quantitative*.

quantitative

A numeric expression of a variable. See *qualitative*.

rad

The unit of measure of absorbed *radiation* dose in terms of energy. One rad is equal to an absorbed *dose* of 100 ergs per gram. (In the metric system of measurements, an erg is a unit of energy. One foot-pound is equal to 13,560,000 ergs.)

radiation

The emitted particles or *photons* from the *nuclei* of *radioactive* atoms. Some elements are naturally radioactive; others are induced to become radioactive by *irradiation* in a *reactor*. Naturally occurring radiation is indistinguishable from induced radiation.

radioactive

Emitting *radioactivity*.

radioactive decay

The process in which one *radionuclide* spontaneously transforms into one or more different radionuclides, which are called decay products.

radioactivity

The property possessed by some elements (for example, uranium) of spontaneously emitting alpha, beta, or *gamma rays* by the *disintegration* of atomic *nuclei*.

radiologically controlled area

An area of the surface repository enclosed by security fences, control gates, lighting, and detection systems established to prevent the spread of radiological contamination. The area would include the facilities and transportation systems required to receive and ship rail and truck waste shipments, prepare *shipping casks* for handling, and load *waste forms* into disposal containers for *emplacement* in the repository. It would also include the facility and systems required to treat and package site-generated *low-level radioactive waste* for offsite disposal.

radionuclide

See *nuclide*.

rail classification yard

A railroad switching yard where railcars arriving in inbound freight trains are classified and reassembled according to their routing to make up outbound freight trains.

rail route

Route from point of origin to the repository.

reactor

See *nuclear reactor*.

release fraction

The fraction of each *isotope* in *spent nuclear fuel* or *high-level radioactive waste* that could be released from a containment in an *accident*.

real disposable income

The dollar income, including the value of transfer payments, available to individuals after taxes have been paid; also referred to as *real disposable personal income*.

reasonably maximally exposed individual

See *receptor*.

receptor

A hypothetical person who is exposed to environmental contaminants (in this case *radionuclides*) in such a way—by a combination of factors including location, lifestyle, dietary habits, etc.—that this individual is representative of the *exposure* of the general population. DOE used this hypothetical individual to evaluate long-term repository performance. The receptor represents the "Reasonably Maximally Exposed Individual (RMEI)" defined in 40 CFR Part 197. The Draft EIS defined the receptor slightly differently and called this hypothetical person the *maximally exposed individual,* which is still used for evaluating short-term impacts.

recharge

The movement of water from an *unsaturated zone* to a *saturated zone*.

recordable cases

Occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) lost workday cases (nonfatal), and (3) the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Record of Decision

A document that provides a concise public record of a decision made by a government agency.

region of influence

The physical area that bounds the environmental, sociologic, economic, or cultural features of interest for the purpose of analysis.

rem

A unit of *dose equivalent.*

remediation

Action taken to permanently remedy a release or threatened release of a hazardous substance to the *environment*, instead of or in addition to removal.

repository

See *geologic repository*.

repository block

The portion of rock in Yucca Mountain that would house the repository, if the site was suitable.

repository horizon

The area within the *repository block* where *emplacement drifts* would be excavated. Also called emplacement horizon.

repository phases

The development of a monitored geologic repository at Yucca Mountain, if approved, would have three phases, as follows:

- *Construction:* Activities during this phase would include preparing the site, constructing surface waste handling and support facilities, excavating and equipping a portion of the repository *subsurface* for initial waste *emplacement*, and conducting initial verification testing of components and systems.

- *Operation and monitoring:* Repository operations activities would include waste receipt, repackaging, and emplacement in the repository; continuing subsurface development for waste *emplacement; monitoring; and maintenance*. Monitoring would begin with the initial emplacement of waste in the repository and would end at repository closure. In addition, the maintenance of repository facilities would continue until the closure of the repository. See *monitoring*, *maintenance*.

- *Closure:* The closure of the *subsurface* repository facilities would include the removal and salvage of equipment and materials; filling of the main *drifts*, access ramps, and ventilation shafts; and sealing of openings, including ventilation shafts, access ramps, and *boreholes*. Surface closure activities would include the construction of monuments to mark the repository location, *decommissioning* and demolition of facilities, and restoration of the site to its approximate condition before the construction of the repository facilities.

respirable fraction

The fraction of *aerosol* released in an *accident* that consists of particles or droplets having aerodynamic effective diameters of 10 microns (about 4 millionths of an inch) or less.

retrieval

The act of removing *radioactive* waste from the underground location at which the waste had been previously emplaced for disposal. Retrieval would be a contingency action, performed only if *monitoring* indicated that the waste needed to be retrieved in order to protect the public health and safety or the environment or to recover resources from *spent nuclear fuel*.

reverse fault

A *fault* in which the relative displacement is along the direction of the dip of the fault plane (*dip-slip fault*), and in which the block above the fault has moved upward in relation to the block below the fault.

riparian

Of, on, or pertaining to the bank of a river or stream, or of a pond or small lake.

riprap

Broken stones or chunks of concrete used as foundation material or in embankments to control water flow or prevent erosion.

risk
: The product of the probability that an undesirable event will occur multiplied by the consequences of the undesirable event.

safe haven
: Designated safe parking locations along transportation routes.

sanitary and industrial solid waste
: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as household waste.

sanitary waste
: Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

saturated zone
: The area below the *water table* where all spaces (*fractures* and rock pores*)* are completely filled with water.

scenario
: A specific set of actions, activities, and assumptions. Scenarios are identified and analyzed to enable the estimation of the range of environmental impacts associated with the *Proposed Action* and the *No-Action Alternative*. The environmental impacts identified from these scenarios provide environmental information to support Departmental decisions about the *alternatives* and *implementing alternatives*.

scoria
: Bubbly, glassy lava rock of basaltic composition that originated as hot, welded materials ejected from a volcano. Small fragments are called “cinders.”

seismic
: Pertaining to, characteristic of, or produced by *earthquakes* or earth vibrations.

seismicity
: A seismic event or activity such as an *earthquake* or earth tremor; *seismic* action.

sensitive structures
: Buildings or structures, usually old and of cultural value, or facilities that house vibration-sensitive equipment, that could be susceptible to ground vibrations, activities, or conditions causing *ground vibrations*.

shaft
: For the Yucca Mountain Repository, an excavation or vertical passage of limited area, compared to its depth, used to ventilate underground facilities.

shielding
: Any material that provides *radiation* protection.

shipment
: The movement of a properly prepared (loaded, unloaded, or empty) *cask* from one site to another and associated activities to ensure compliance with applicable regulations.

shipping cask
: A heavily shielded massive container that meets regulatory requirements for shipping *spent nuclear fuel* or *high-level radioactive waste*. See *cask*.

single-purpose (storage or transportation) cask
: A heavily shielded massive container for the dry storage of *spent nuclear fuel*; it is usable for either storage or transportation but not for *emplacement* in a repository. See *cask*.

site boundary
: The boundary of the land withdrawal area used for analytical purposes in this EIS. See *land withdrawal area*.

site characterization
: Activities associated with the determination of the suitability of the Yucca Mountain site as a *monitored geologic repository*. DOE constructed the *Exploratory Studies Facility* to support the following activities related to the determination of site suitability, including surface facilities and *subsurface* ramps and *drifts*:

- Gather and evaluate surface and subsurface site data
- Predict the performance of the repository
- Prepare the repository design
- Assess the performance of the system against the required Code of Federal Regulations and program performance criteria

Some of the exploratory surface and subsurface facilities would be enhanced during the repository construction phase (see *repository phases*); others would be removed, demolished, or relocated, as necessary. Data gathering associated with site characterization would end with any Site Recommendation decision.

site-generated waste
: Waste or wastewater generated at the *monitored geologic repository* and related transportation facilities.

Site Recommendation
: A recommendation by the Secretary of Energy to the President that the Yucca Mountain site be approved for development as the Nation's first *spent nuclear fuel* and *high-level radioactive waste* repository.

soil recovery
: The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

sound barrier

Natural or artificial structures that block or interfere with the propagation of sound; examples include terrain features and manmade structures (buildings, walls, etc.).

source term

Types and amounts of radionuclides that are the source of a potential release of *radioactivity*.

Spaghetti Bowl

As used in this EIS, the intersection of Interstate Highway 15 and U.S. Highway 93/95 in Las Vegas, Nevada.

spalling

(1) Flaking off of corrosion products from the metal *substrate* as it undergoes corrosion. The layer of corroded material thickens. The spalling could be caused by an expansive action of the corrosion products because they occupy a greater volume than the uncorroded metal substrate. (2) Flaking, chipping, or cracking at the opening of a *borehole*, *shaft*, or other rock excavation.

Special-Performance-Assessment-Required (SPAR) wastes

Low-level radioactive wastes generated in DOE production reactors, research reactors, reprocessing facilities, and research and development activities that exceed the Nuclear Regulatory Commission Class C shallow-land burial disposal limits.

spent nuclear fuel

Fuel that has been withdrawn from a *nuclear reactor* following *irradiation*, the component elements of which have not been separated by reprocessing. For this project, this refers to (1) intact, nondefective *fuel assemblies*, (2) failed fuel assemblies in canisters, (3) fuel assemblies in canisters, (4) consolidated fuel rods in canisters, (5) nonfuel assembly hardware inserted in *pressurized-water reactor* fuel assemblies, (6) fuel channels attached to *boiling-water reactor* fuel assemblies, and (7) nonfuel assembly hardware and structural parts of assemblies resulting from consolidation in *canisters*.

spoils areas

Areas outside the rail corridor for the deposition of excavated materials from rail line development.

stakeholder

A person or organization with an interest in or affected by DOE actions (representatives from Federal, state, tribal, or local agencies; members of Congress or state legislatures; unions, educational groups, environmental groups, industrial groups, etc.; and members of the general public).

storage

The collection and containment of waste or *spent nuclear fuel* in a way that does not constitute *disposal* of the waste or *spent nuclear fuel* for the purposes of awaiting treatment or disposal capacity.

storage cask

See *cask*.

storage container

See *cask*.

stratigraphy

The branch of geology that deals with the definition and interpretation of rock strata, the conditions of their formation, character, arrangement, sequence, age, distribution, and especially their correlation by the use of fossils and other means of identification. See *stratum*.

stratosphere

The atmospheric shell above the troposphere and below the mesosphere. It extends from 10 to 20 kilometers (6 to 12 miles) to about 53 kilometers (33 miles) above the surface.

stratum

A sheetlike mass of sedimentary rock or earth of one kind lying between beds of other kinds.

strike-slip fault

A fault with purely horizontal relative displacement.

subcritical

Having an effective multiplication constant less than 1, so that a self-supporting *chain reaction* cannot be maintained in a *nuclear reactor*.

subsidiary fault

See *intrablock fault*.

substrate

Basic surface on which a material adheres.

subsurface

A zone below the surface of the Earth, the *geologic* features of which are principally layers of rock that have been tilted or faulted and are interpreted on the basis of drill hole records and geophysical (*seismic* or rock vibration) evidence. In general, it is all rock and solid materials lying beneath the Earth's surface.

sulfur dioxide

A pungent, colorless gas produced during the burning of sulfur-containing fossil fuels. It is the main pollutant involved in the formation of acid rain. Coal- and oil-burning electric utilities are the major source of sulfur dioxide in the United States. Inhaled sulfur dioxide can damage the human respiratory tract and can severely damage vegetation. See *criteria pollutants*, *ambient air quality standards*.

sulfur oxides

A mixture of sulfur dioxide, sulfur trioxide, and inorganic sulfites and sulfates. Sulfur dioxide combines with oxygen in the air to form sulfur trioxide and microscopic aerosol sulfite and sulfate particles, all of which are lung irritants. See *criteria pollutants*, *ambient air quality standards*.

supernate

A concentrated form of *radioactive* waste that floats to the top of an undisturbed container of liquid *high-level radioactive waste*.

thermal loading

(1) The spatial density at which *waste packages* would be emplaced within the repository as characterized by the areal power density and the *areal mass loading*. (2) The application of heat to a system, usually measured in terms of watts per unit area. The thermal load for a repository would be the watts per acre produced by the *radioactive* waste in the active disposal area.

thermal shunt

A metal structure, usually aluminum, that would be added to *waste packages* as needed to greatly improve heat conduction between the center of the waste package and the outer edge, thereby providing a reliable means to keep the temperature of the *cladding* within design limits.

threatened species

A species that is likely to become an *endangered species* within the foreseeable future throughout all or a significant part of its range.

thrust fault

A *reverse fault* in which the angle of the fault plane is less than 45 degrees.

total employment

The sum of direct and indirect employment resulting from initiation of an activity. Direct employment consists of jobs performing the activity. Indirect employment consists of jobs in other activities supporting the direct employees. Also defined as composite employment.

total population

The sum of all people associated with direct and indirect employees and their families resulting from initiation of an activity.

Total System Performance Assessment

A risk assessment that quantitatively estimates how the proposed Yucca Mountain Repository system could perform under the influence of specific features, events, and processes, incorporating *uncertainty* in the models and data. See *performance assessment*.

toxic air pollutants

Hazardous pollutants not listed as either *criteria pollutants* or *hazardous pollutants*.

traditional cultural property

A property that is eligible for inclusion in the National Register of Historic Places because of its association with cultural practices or beliefs of a living community that are rooted in that community's history, and are important in maintaining the continuing cultural identity of the community. Culture includes the traditions, beliefs, practices, lifeways, arts, crafts, and social institutions of any community, be it a Native American tribe, a local ethnic group, or the people of the Nation as a whole. Properties can include buildings, structures, and sites; groups of buildings, structures, or sites forming historic districts; and individual objects.

transpiration

The process by which water enters a plant through its root system, passes through its vascular system, and is released into the atmosphere through openings in its outer covering. It is an important process for removal of water that has infiltrated below the zone where it could be removed by evaporation.

transuranic waste

Waste materials (excluding *high-level radioactive waste* and certain other waste types) contaminated with alpha-emitting radionuclides that are heavier than uranium with half-lives greater than 20 years and that occur in concentrations greater than 100 nanocuries per gram. Transuranic waste results primarily from treating and fabricating plutonium as well as research activities at DOE defense installations.

trunnion

A projection from a vessel or other piece of equipment that facilitates attachment to a lifting device.

tuff

Igneous rock formed from compacted volcanic fragments from *pyroclastic* (explosively ejected) flows with particles generally smaller than 4 millimeters (about 0.16 inch) in diameter—the most abundant type of rock at the Yucca Mountain site. Nonwelded tuff results when volcanic ash cools in the air sufficiently that it doesn't melt together, yet later becomes rock through compression. See *welded tuff*.

ultraviolet radiation

Electromagnetic radiation with wavelengths from 4 to 400 nanometers. This range begins at the short wavelength limit of visible light and overlaps the wavelengths of long *x-rays* (some scientists place the lower limit at higher values, up to 40 nanometers). Also known as ultraviolet light.

uncanistered spent nuclear fuel

Commercial spent nuclear fuel placed directly into shipping casks. At the repository, *spent nuclear fuel* assemblies would be removed from the *shipping cask* in a *disposal container* or in the fuel pool to accomodate *blending*.

uncertainty

A measure of how much a calculated or estimated value that is used as a reasonable guess or prediction might vary from the unknown true value.

unique farmland

Land other than *prime farmland* that is used for the production of specific high-value food and fiber crops such as citrus, tree nuts, olives, cranberries, fruits, and vegetables.

unsaturated zone

The zone of soil or rock below the ground surface and above the *water table*.

vadose zone

See *unsaturated zone*.

variation

As used in the transportation analysis in this EIS, a strip of land, approximately 400 meters (0.25 mile) wide, from one point along a corridor to another point along the same corridor that describes a different route. See *alternate*, *option*, *corridor*.

Viability Assessment

An assessment of the prospects for geologic disposal at the Yucca Mountain site, based on repository and *waste package* design, a *Total System Performance Assessment*, a *License Application* plan, and repository cost and schedule estimates. DOE issued the *Viability Assessment of a Repository at Yucca Mountain* in December 1998.

vicinity (in relation to the Yucca Mountain Repository)

A general term used in nonspecific discussions in this EIS about the area around the Yucca Mountain site.

viewshed

A total field of vision or a vista. In particular, an area with visual boundaries seen from various points within the area.

vitrification

A waste treatment process that uses glass (for example, *borosilicate glass*) to encapsulate or immobilize *radioactive* wastes.

vitrophyre

A volcanic rock with large crystals embedded in a glassy, obsidian-like matrix.

waste form

A generic term that refers to the different types of *radioactive* wastes.

waste package

A sealed container containing waste that is ready for *emplacement*. The waste package would contain the *waste form* and any internal structures necessary for structural support, thermal control, or nuclear control.

water table

(1) The upper limit of the *saturated zone* (the portion of the ground wholly saturated with water). (2) The upper surface of a zone of saturation above which the majority of pore spaces and fractures are less than 100 percent saturated with water most of the time (*unsaturated zone*) and below which the opposite is true (saturated zone).

welded tuff

A *tuff* deposited under conditions where the particles making up the rock were heated sufficiently to cohere. In contrast to nonwelded tuff, welded tuff is denser, less porous, and more likely to be fractured (which increases *permeability*).

wetland

A shoreline or other area, such as a marsh or swamp, that is saturated with moisture, especially when thought of as the natural habitat of wildlife.

wet storage

Storage of *radioactive* material that uses water for cooling or *shielding*, such as a spent nuclear fuel storage pool.

worker year

2,000 hours of paid labor; a project requiring 1.5 worker years would take 3,000 hours to complete.

X-rays

Penetrating electromagnetic *radiation* having a wavelength much shorter than that of visible light. X-rays are identical to *gamma rays* but originate outside the *nucleus*, either when the inner orbital *electrons* of an excited atom return to their normal state or when a metal target is bombarded with high-speed electrons.

Yucca Mountain Repository EIS

See *environmental impact statement (EIS)*.

Yucca Mountain site (the site):

The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

zeolite

Any of a group of hydrated silicates of aluminum with alkali metals, commonly occurring as secondary minerals in cavities in basic volcanic rocks.

zirconium alloy

An alloy material containing the element zirconium that might have any of several compositions. It is used as a *cladding* material.

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15. INDEX

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CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor		
exa-	E	1,000,000,000,000,000,000	=	10^{18}
peta-	P	1,000,000,000,000,000	=	10^{15}
tera-	T	1,000,000,000,000	=	10^{12}
giga-	G	1,000,000,000	=	10^{9}
mega-	M	1,000,000	=	10^{6}
kilo-	k	1,000	=	10^{3}
deca-	D	10	=	10^{1}
deci-	d	0.1	=	10^{-1}
centi-	c	0.01	=	10^{-2}
milli-	m	0.001	=	10^{-3}
micro-	µ	0.000 001	=	10^{-6}
nano-	n	0.000 000 001	=	10^{-9}
pico-	p	0.000 000 000 001	=	10^{-12}

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Final

Environmental Impact Statement
for a
Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Volume II
Appendixes A through O

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the U.S. Department of Energy (DOE) limited the use of acronyms and abbreviations in this environmental impact statement. In addition, acronyms and abbreviations are defined the first time they are used in each chapter or appendix. The acronyms and abbreviations used in the text of this document are listed below. Acronyms and abbreviations used in tables and figures because of space limitations are listed in footnotes to the tables and figures.

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
LCF	latent cancer fatality
MTHM	metric tons of heavy metal
NEPA	National Environmental Policy Act, as amended
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act, as amended
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
REMI	Regional Economic Models, Inc.
RMEI	reasonably maximally exposed individual
Stat.	United States Statutes
TSPA	Total System Performance Assessment
U.S.C.	United States Code

UNDERSTANDING SCIENTIFIC NOTATION

DOE has used scientific notation in this EIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number between 1 and 10 and a positive or negative power of 10. Examples include the following:

Positive Powers of 10
$10^1 = 10 \times 1 = 10$
$10^2 = 10 \times 10 = 100$
and so on, therefore,
10^6 = 1,000,000 (or 1 million)

Negative Powers of 10
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/100 = 0.01$
and so on, therefore,
10^{-6} = 0.000001 (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are three chances in 1,000,000 that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.

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Appendix A

Inventory and Characteristics of Spent Nuclear Fuel, High-Level Radioactive Waste, and Other Materials

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APPENDIX A. INVENTORY AND CHARACTERISTICS OF SPENT NUCLEAR FUEL, HIGH-LEVEL RADIOACTIVE WASTE, AND OTHER MATERIALS

A.1 Introduction

This appendix describes the inventory and characteristics of the spent nuclear fuel and high-level radioactive waste that the U.S. Department of Energy (DOE) anticipates it would place in a monitored geologic repository at Yucca Mountain. It includes information about other highly radioactive material that DOE could dispose of in the proposed repository. It also provides information on the background and sources of the material, present storage conditions, the final disposal forms, and the amounts and characteristics of the material. The data provided in this appendix are the best available estimates of projected inventories.

The Proposed Action inventory evaluated in this environmental impact statement (EIS) consists of 70,000 metric tons of heavy metal (MTHM), comprised of 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM of DOE materials. The DOE materials consist of 2,333 MTHM of spent nuclear fuel and 4,667 MTHM (8,315 canisters) of solidified high-level radioactive waste. The inventory includes surplus weapons-usable plutonium, which would be in the forms of spent mixed-oxide fuel and immobilized plutonium.

The Nuclear Waste Policy Act, as amended (also called the NWPA), prohibits the U.S. Nuclear Regulatory Commission from approving the emplacement of more than 70,000 MTHM in the first repository until a second repository is in operation [Section 114(d)]. However, in addition to the Proposed Action, this EIS evaluates the cumulative impacts for two additional inventories (referred to as Inventory Modules 1 and 2):

- The Module 1 inventory consists of the Proposed Action inventory plus the remainder of the total projected inventory of commercial spent nuclear fuel (for maximum projections, see Section A.2.1.5.1), high-level radioactive waste, and DOE spent nuclear fuel. Emplacement of Inventory Module 1 wastes in the repository would raise the total amount emplaced above 70,000 MTHM. As mentioned above, emplacement of more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste would require legislative action by Congress unless a second licensed repository was in operation.

- Inventory Module 2 includes the Module 1 inventory plus the inventories of the candidate materials, commercial Greater-Than-Class-C low-level radioactive waste and DOE Special-Performance-Assessment-Required waste. There are several reasons to evaluate the potential for disposing of these candidate materials in a monitored geologic repository in the near future. Because both materials exceed Class C low-level radioactive limits for specific radionuclide concentrations as defined in 10 CFR Part 61, they are generally unsuitable for near-surface disposal. Also, the Nuclear Regulatory Commission specifies in 10 CFR 61.55(a)(2)(iv) the disposal of Greater-Than-Class-C waste in a repository unless the Commission approved disposal elsewhere. Further, during the scoping process for this EIS, several commenters requested that DOE evaluate the disposal of other radioactive waste types that might require isolation in a repository. Disposal of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes at the proposed Yucca Mountain Repository could require a determination by the Nuclear Regulatory Commission that these wastes require permanent isolation. The present 70,000-MTHM limit on waste at the Yucca Mountain Repository could have to be addressed either by legislation or by opening a second licensed repository.

The Yucca Mountain Science and Engineering Report evaluates the 70,000-MTHM Proposed Action inventory as the base case for analysis (DIRS 153849-DOE 2001, all) and considers a repository layout for a best estimate “full inventory” case (DIRS 153849-DOE 2001, p. 2-83), which would accommodate approximately 97,000 MTHM.

A.1.1 INVENTORY DATA SUMMARY

There are six general inventory categories, as follows:

- Commercial spent nuclear fuel
- DOE spent nuclear fuel
- High-level radioactive waste
- Surplus weapons-usable plutonium
- Commercial Greater-Than-Class-C waste
- DOE Special-Performance-Assessment-Required waste

This section summarizes the detailed inventory data in Section A.2. The data provide a basis for the impact analysis in this EIS. Data are provided for the candidate materials included in the initial 70,000 MTHM for the Proposed Action and other inventory that is not currently proposed but might be considered for repository disposal in the foreseeable future.

This summary provides general descriptive and historic information about each waste type, including the following:

- Primary purpose and use of the data
- General comparison of the data between waste types
- Potential for change in inventory data

Table A-1 lists the inventory data that DOE used in the EIS analyses and their descriptions throughout the document.

A.1.1.1 Sources

Figure A-1 shows the locations of generators or sources of spent nuclear fuel and high-level radioactive waste. Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation. The Proposed Action includes the disposal of 63,000 MTHM of commercial spent nuclear fuel in the repository. More than 99 percent of the commercial spent nuclear fuel would come from commercial nuclear reactor sites in 33 states (DIRS 104382-DOE 1995, all). In addition, DOE manages an inventory of spent nuclear fuel. The Proposed Action includes 2,333 MTHM of spent nuclear fuel from four DOE locations: the Savannah River Site in South Carolina, the Hanford Site in Washington, the Idaho National Engineering and Environmental Laboratory, and Fort St. Vrain in Colorado.

High-level radioactive waste is the highly radioactive material resulting from the reprocessing or treatment of spent nuclear fuel. The Proposed Action includes disposing of 4,667 MTHM of high-level radioactive waste in the repository. High-level radioactive waste is stored at the Savannah River Site, the Hanford Site, the Idaho National Engineering and Environmental Laboratory, and the West Valley Demonstration Project in New York.

The President has declared an amount of plutonium to be surplus to national security needs (DIRS 118979-DOE 1999, p. 1-3). This surplus weapons-usable plutonium includes purified plutonium, nuclear weapons components, and plutonium residues. This inventory is included in the Proposed Action, and the Department would dispose of it as either spent mixed oxide fuel from a commercial nuclear reactor

Table A-1. Use of Appendix A radioactivity inventory data in EIS chapters and appendixes (page 1 of 2).

Item[a]	Appendix A	EIS section
Number of commercial nuclear sites	Table A-3	1.1, 2.2, 2.2.2, 2.4.1, 6.1, Ch. 7 introduction, 7.2, 7.2.1, 7.3, J.1.3.1.1
Number of DOE sites	A.1.1.1	1.1, 2.2, 2.2.2, 2.4.1, 6.1, Ch. 7 introduction, 7.2, 7.2.1, 7.3
Mapped location of sites	Figure A-1	Figure 1-1, several Chapter 6, 7, App. J and K figures
Commercial SNF material	A.2.1.5.3	1.2.2.1
Commercial SNF dimensions	Table A-18	1.2.1 and Figure 1-2
Commercial SNF cladding material	A.2.1.5.3	1.2.2.1, K.2.1.4.1
Percentage of commercial SNF with stainless-steel cladding	A.2.1.5.3	1.2.2.1, 5.5.1, K.2.1.4.1
MOX SNF part of commercial SNF Proposed Action	A.2.4.5.1.1	1.2.2.1, 1.2.4
Number of sites with existing or planned ISFSIs	Table A-4	1.2.1
Amount of commercial SNF projected for each site	Tables A-7 and A-8	6.1.1, K.2.1.6
DOE SNF storage locations	Table A-20	1.2.2.2, K.2.1.6
HLW generators	A.2.3.2	1.2.3
HLW vitrification status	A.2.3.3	1.2.3
Weapons-usable Pu declared surplus	A.2.4.1	1.2.4
Two forms: MOX and immobilized Pu	A.2.4.1	1.2.4
Proposed Action inventory	A.1	1.2.2.1, 2.1, 5.1, 8.1.2.1, K.2.2
Total projected inventory commercial SNF	Figure A-2	7.2, 7.3, 8.1.2.1
Total projected inventory DOE SNF	Figure A-2	7.2, 7.3, 8.1.2.1, K.2.2
Total projected inventory HLW	Figure A-2	7.2, 7.3, 8.1.2.1, K.2.2
Total projected GTCC waste	Table A-54	7.3, 8.1.2.1, I.3.1.3
Total projected SPAR waste	Table A-59	7.3, 8.1.2.1, I.3.1.3
Kr-85 (gas) is contained in fuel gap of commercial SNF	A.2.1.5.2	4.1.2.3.2, H.2.1.4.1.2
Radionuclide inventory for commercial SNF	Tables A-9, A-10, and A-11	4.1.8.1, H.2.1.4, Table H-4, J.1.4.2.1, K.2.2
Cs-137, actinide, and total curies contained in a rail shipping cask for commercial SNF, HLW, DOE SNF, and naval fuel	Derived from Tables A-10, A-21, and A-28	Table J-12, Table J-15
Radiological inventory of GTCC and SPAR waste much less than commercial SNF or HLW	Derived from Tables A-9, A-21, A-28, A-57, and Section A.2.6.4	8.2.7, 8.2.8, 8.4.1.1, F.3
Average radionuclide inventory per package for SPAR and GTCC waste	Derived from Table A-57 and Section A.2.6.4	8.3.1.1, Table I-7
C-14 (gas) is contained in fuel gap of commercial SNF	Tables A-9, A-10, and A-11	5.5, 8.3.1.1, H.2.1.4.1.2, I.3.3, I.7
PWR burnup, initial enrichment, and average cooling time	A.2.1.5	G.2.3.2, J.1.4.2.1
BWR burnup, initial enrichment, and average cooling time	A.2.1.5	G.2.3.2
DOE SNF radionuclide inventory	Table A-21	

Table A-1. Use of Appendix A radioactivity inventory data in EIS chapters and appendixes (page 2 of 2).

Item[a]	Appendix A	EIS section
Assumed packaging method for GTCC and SPAR	A.2.5.4, A.2.6.4	I.3.1.3
Chemical makeup of waste inventory	Tables A-15, A-16, A-22, A-32, A-33, A-34, A-35, A-36, and A-37	Table I-8
MTHM per assembly for PWR and BWR	Table A-17	J.1.3.1.1
Most HLW stored in underground vaults	A.2.3.3	K.2.1.5.3

a. Abbreviations: SNF = spent nuclear fuel; MOX = mixed oxide; ISFSI = independent spent fuel storage installation; HLW = high-level radioactive waste; Pu = plutonium; GTCC = Greater-Than-Class-C; SPAR = Special-Performance-Assessment-Required; MTHM = metric tons of heavy metal; Kr = krypton; Cs = cesium; PWR = pressurized-water reactor; BWR = boiling-water reactor.

(that is, commercial spent nuclear fuel) or immobilized plutonium in a high-level radioactive waste canister (that is, as high-level radioactive waste), or a combination of these two inventory categories (DIRS 118979-DOE 1999, p. 1-3). Spent mixed-oxide fuel would come from one or more of the existing commercial reactor sites. DOE has selected the Savannah River site in South Carolina as the location for the immobilized plutonium disposition facilities.

For purposes of analysis, this EIS assumes that the high-level radioactive waste canisters, which would contain immobilized plutonium and borosilicate glass, would come from the Savannah River Site.

Greater-Than-Class-C waste is waste with concentrations of certain radionuclides that exceed the Class C limits stated in 10 CFR Part 61, thereby making it unsuitable for near-surface disposal. Greater-Than-Class-C waste is generated by a number of sources including commercial nuclear utilities, sealed radioactive sources, and wastes from "other generators." These other generators include carbon-14 users, industrial research and development applications, fuel fabricators, university reactors, and others. These wastes are currently stored at the commercial and DOE sites and exist in most states. They are included in Inventory Module 2 of the EIS but are not part of the Proposed Action.

Special-Performance-Assessment-Required wastes are also Greater-Than-Class-C wastes managed by DOE and are stored primarily at the Hanford Site, Idaho National Engineering and Environmental Laboratory, West Valley Demonstration Project, and Oak Ridge National Laboratory in Tennessee. These wastes are included in Inventory Module 2 of the EIS but are not part of the Proposed Action.

A.1.1.2 Present Storage and Generation Status

Commercial spent nuclear fuel is stored at reactor sites in either a spent fuel pool or in a dry storage configuration generally referred to as an independent spent fuel storage installation. Through 1999, approximately 40,000 MTHM of commercial spent nuclear fuel has been discharged from reactors (DIRS 153849-DOE 2001, p. 1-10). DOE spent nuclear fuel is also stored either underwater in basins or in a dry storage configuration.

As discussed in the next section, DOE would receive high-level radioactive waste at the repository in a solidified form in stainless-steel canisters. Until shipment to the repository, the canisters would be stored at the commercial and DOE sites. With the exception of the West Valley Demonstration Project, filled canisters are stored in below-grade facilities. The West Valley canisters would be stored in an above-ground shielded facility.

Figure A-1. Locations of commercial and DOE sites and Yucca Mountain.

A.1.1.3 Final Waste Form

Other than drying or potential repackaging, treating is not necessary for commercial spent nuclear fuel. Therefore, the final form would be spent nuclear fuel either as bare intact assemblies or in sealed canisters. Bare intact fuel assemblies are those with structural and cladding integrity such that they can be handled and shipped to the repository in an approved shipping container for repackaging in a waste package in the Waste Handling Building. Other assemblies would be shipped to the repository in canisters that were either intended or not intended for disposal. Canisters not intended for disposal would be opened and their contents repackaged in waste packages in the Waste Handling Building.

For most of the DOE spent nuclear fuel categories, the fuel would be shipped in disposable canisters (canisters that can be shipped and are suitable for direct insertion into waste packages without being opened) in casks licensed by the Nuclear Regulatory Commission. Uranium oxide fuels with intact zirconium alloy cladding are similar to commercial spent nuclear fuel and could be shipped either in DOE standard canisters or as bare intact assemblies. Uranium metal fuels from Hanford and aluminum-based fuels from the Savannah River Site could require additional treatment or conditioning before shipment to the repository. If treatment was required, these fuels would be packaged in DOE disposable canisters. Category 14 sodium-bonded fuels are also expected to require treatment before disposal.

High-level radioactive waste shipped to the repository would be in stainless-steel canisters. The waste would have undergone a solidification process that yielded a leach-resistant material, typically a glass form called borosilicate glass. In this process, the high-level radioactive waste is mixed with glass-forming materials, heated and converted to a durable glass waste form, and poured into stainless-steel canisters (DIRS 104406-Picha 1997, Attachment 4, p. 2). Ceramic and metal waste matrices would be sent to the repository from Argonne National Laboratory-West in Idaho. The ceramic and metal matrices would be different solidified mixtures that also would be in stainless-steel canisters. These wastes would be the result of the electrometallurgical treatment of sodium bonded fuels.

As briefly described in Section A.1.1.1, the surplus weapon-usable plutonium could be sent to the repository in two different waste forms—spent mixed-oxide fuel assemblies or an immobilized plutonium ceramic form in a high-level radioactive waste canister and surrounded by high-level radioactive waste. The spent mixed-oxide fuel assemblies would be very similar to conventional low-enriched uranium assemblies and DOE would treat them as such. The immobilized plutonium would be placed in small cans, inserted in the high-level radioactive waste canisters, and covered with molten borosilicate glass (can-in-canister technique). The canisters containing immobilized plutonium and high-level radioactive waste would be externally identical to the normal high-level radioactive waste canisters.

A.1.1.4 Waste Characteristics

A.1.1.4.1 *Mass and Volume*

As discussed in Section A.1, the Proposed Action includes 70,000 MTHM in the forms of commercial spent nuclear fuel, DOE spent nuclear fuel, high-level radioactive waste, and surplus weapons-usable plutonium. Figure A-2 shows percentages of MTHM included in the Proposed Action and the relative amounts of the totals of the individual waste types included in the Proposed Action. As stated above, the remaining portion of the wastes is included in Inventory Module 1. Because Greater-Than-Class-C and Special-Performance-Assessment-Required wastes are measured in terms of volume, Figure A-3 shows the relative volume of the wastes in Inventory Module 2 compared to the inventory in Module 1.

The No-Action Alternative (see Chapter 7 and Appendix K) used this information to estimate the mass and volume of the spent nuclear fuel and high-level radioactive waste at commercial and DOE sites in five regions of the contiguous United States.

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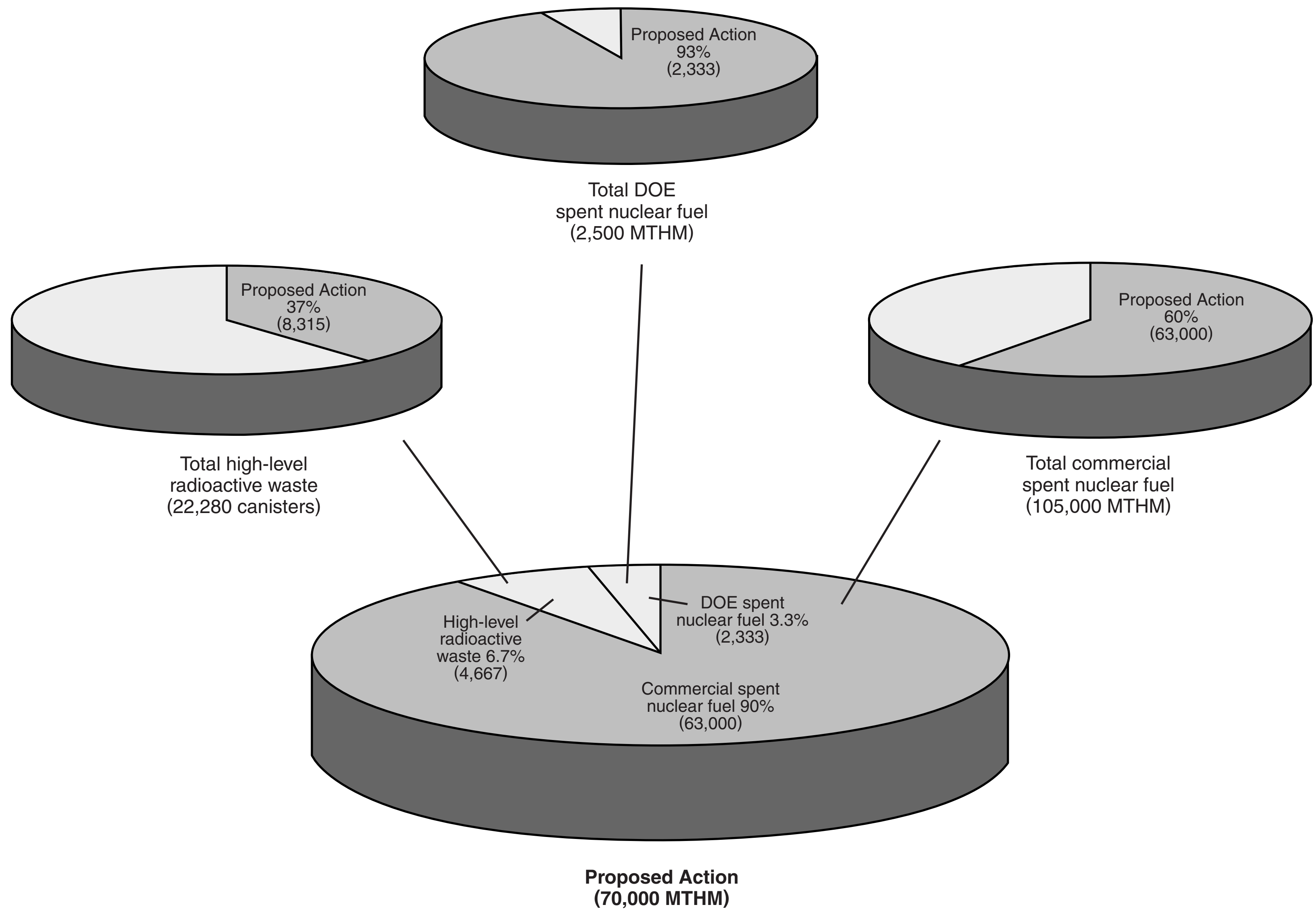
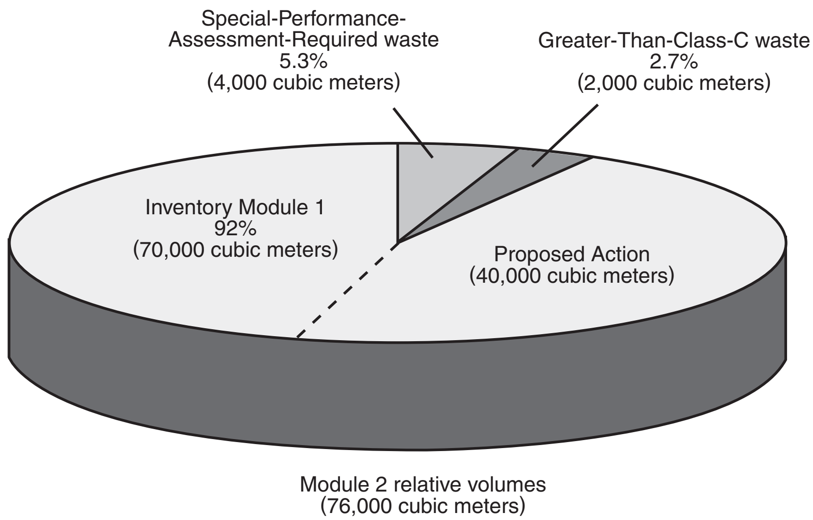


Sources: DIRS 103493-DOE (1997, page 32); DIRS 148240-Dirkmaat (1998, all); DIRS 104406-Picha (1997, Attachment 1, page 1); DIRS 104407-Picha (1998, Attachment 1).

Figure A-2. Proposed Action spent nuclear fuel and high-level radioactive waste inventory.



To convert cubic meters to cubic yards, multiply by 1.3079.

Sources: DIRS 148240-Dirkmaat (1998, all); DIRS 101798-DOE (1994, all); DIRS 101815-DOE (1997, p. 1-8); DIRS 104394-Heath (1998, Appendixes B and C); DIRS 104406-Picha (1997, Attachment 1, p. 1); DIRS 104407-Picha (1998, Attachment 1); DIRS 104411-Picha (1998, all).

Figure A-3. Inventory Module 2 volume.

The mass and volume data for commercial spent nuclear fuel are based on annual tracking of current inventories and projections of future generations. Because increases in spent nuclear fuel inventories due to plant life extensions have been factored into the Module 1 and 2 inventories, DOE anticipates few changes in the overall mass and volume projections for this waste type. The data projections for DOE spent nuclear fuel are fairly stable because most of the projected inventory already exists, as opposed to having a large amount projected for future generation. Mass and volume data for high-level radioactive waste estimates are not as reliable. Most high-level radioactive waste currently exists as a form other than solidified borosilicate glass. The solidification processes at the Savannah River Site and West Valley Demonstration Project began in the mid-1990s; therefore, their resulting masses and volumes are known. However, the processes at the Idaho National Engineering and Environmental Laboratory and the Hanford Site have not started. Therefore, there is some uncertainty about the mass and volume that would result from those processing operations. For this analysis, DOE assumed that the high-level radioactive waste from the Hanford Site and the Idaho National Engineering and Environmental Laboratory would represent approximately 63 and 6 percent of the total high-level radioactive waste inventory, respectively, in terms of the number of canisters.

A.1.1.4.2 *Radionuclide Inventories*

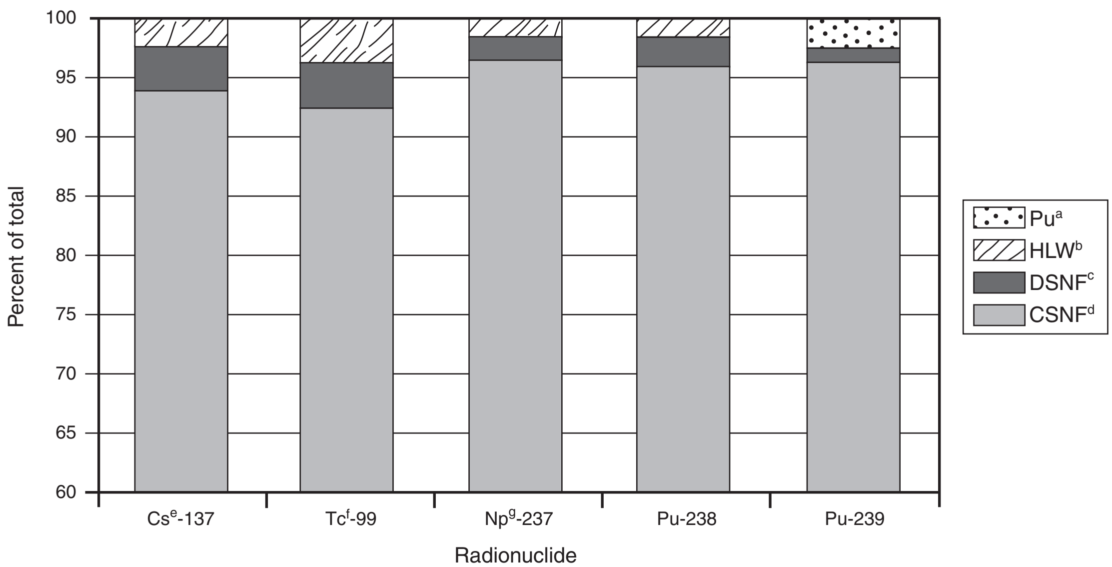
The primary purpose of presenting these data is to quantify the radionuclide inventory expected in the projected waste types. These data were used for accident scenario analyses associated with transportation, handling, and repository operations.

In a comparison of the relative amounts of radioactivity in a particular waste type, radionuclides of concern depend on the analysis being performed. For example, cesium-137 is the primary radionuclide of concern when reviewing preclosure impacts and shielding requirements. For postclosure impacts, the repository performance assessment identified technetium-99 and neptunium-237 as the nuclides that provide the greatest impacts. Plutonium-238 and -239 are shown in Chapter 7 to contribute the most to doses for the No-Action Alternative. Table A-2 presents the inventory of each of these radionuclides included in the Proposed Action. Figure A-4 shows that at least 92 percent of the total inventory of each of these radionuclides is in commercial spent nuclear fuel.

Table A-2. Selected radionuclide inventory for the Proposed Action (curies).[a]

Radionuclide[b]	Commercial spent nuclear fuel	DOE spent nuclear fuel	High-level radioactive waste	Surplus plutonium	Totals
Cesium-137	4.5×10^9	1.7×10^8	1.7×10^8	NA[c]	4.8×10^9
Technetium-99	9.5×10^5	2.9×10^4	2.1×10^4	NA	1.0×10^6
Neptunium-237	3.0×10^4	4.8×10^2	4.5×10^2	NA	3.1×10^4
Plutonium-238	2.4×10^8	5.6×10^6	3.0×10^6	7.6×10^4	2.5×10^8
Plutonium-239	2.4×10^7	3.8×10^5	4.4×10^4	1.0×10^6	2.5×10^7

a. Source: Compiled from Tables A-11, A-21, A-28, A-29, A-30, A-31, A-50, and A-51.
b. Half-lives are listed in Table A-11.
c. NA = not applicable.



a. Pu = surplus weapons-usable plutonium; included in Proposed Action as spent nuclear fuel and high-level radioactive waste.
b. HLW = high-level radioactive waste.
c. DSNF = DOE spent nuclear fuel.
d. CSNF = commercial spent nuclear fuel
e. Cs = Cesium
f. Tc = Technetium
g. Np = Neptunium

Source: Table A-2.

Figure A-4. Proposed Action radionuclide distribution by material type.

A.1.1.4.3 *Chemical Composition*

The appendix presents data for the chemical composition of the primary waste types. For commercial spent nuclear fuel, the elemental composition of typical pressurized-water and boiling-water reactor fuel is provided on a per-assembly basis. Data are also provided on the number of stainless-steel clad assemblies in the current inventory.

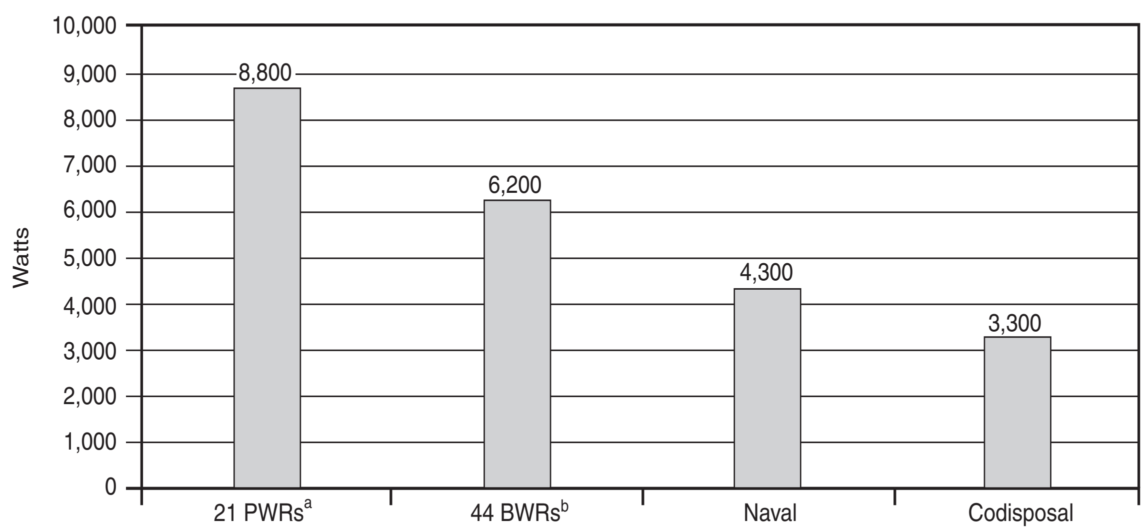
For DOE spent nuclear fuel and high-level radioactive waste, this appendix contains tables that describe the composition of the total inventory of the spent nuclear fuel (by representative category) or high-level radioactive waste (by site).

A.1.1.4.4 *Thermal Output*

Thermal generation data associated with each material type are provided in this appendix.

The data presented in the thermal output sections of this appendix for each waste type are presented as watts per assembly or MTHM for commercial spent nuclear fuel, and watts per canister for DOE spent nuclear fuel or high-level radioactive waste. Figure A-5 normalizes these data into a common, watts-per-waste-package comparison. The following waste packages are compared: one containing 21 average pressurized-water reactor assemblies, one containing 44 average boiling-water reactor assemblies, a codisposal waste package containing five high-level radioactive waste canisters and one DOE spent nuclear fuel canister, and a waste package containing one dual-purpose canister of naval spent nuclear fuel (also a DOE spent fuel).

Figure A-5 uses conservative assumptions to illustrate the bounding nature of the thermal data for commercial spent nuclear fuel. The commercial spent nuclear fuel data represent average assemblies that are assumed to have cooled for about 25 years. The naval spent nuclear fuel data are a best estimate of the thermal generation of a canister of naval spent nuclear fuel at a minimum cooling time of 5 years. The thermal data selected for the high-level radioactive waste are conservatively represented by the canisters from the Savannah River Site and are combined with the highest values of thermal output from all projected DOE spent nuclear fuel categories. As noted in Chapter 2, blending of hot and cold commercial spent nuclear fuel could be employed to meet waste package thermal load limits.



a. PWR = pressurized-water reactor.
b. BWR = boiling-water reactor.

Source: Tables A-17 and A-23.

Figure A-5. Thermal generation (watts per waste package).

A.1.1.4.5 *Canister Data*

Commercial spent nuclear fuel, which would be shipped in canisters not suitable for disposal, would be removed from the canister and placed in a waste package. Typically, DOE spent nuclear fuel and high-level radioactive waste would be sent to the repository in disposable canisters. The design specifications for DOE spent nuclear fuel canisters are in DIRS 137713-DOE (1998, all). These canisters are generally of two diameters—nominally 46 and 61 centimeters (18 and 24 inches). They also would be designed for two different lengths, nominally 3 and 4.5 meters (10 and 15 feet), to enable codisposal with high-level radioactive waste canisters. Certain DOE spent nuclear fuel categories require specific disposal canister designs. Naval fuels would be sent to the repository in disposable canisters, which are described in DIRS 125735-Guida (1997, all) and DIRS 101941-USN (1996, pp. 3-1 to 3-11). N-Reactor fuels from the

Hanford Site would be sent to the repository in multicanister overpacks 64 centimeters (25.3 inches) in diameter, 420 centimeters (65 inches) long, which are described in DIRS 148489-DE&S Hanford (1997, all).

High-level radioactive waste would be sent to the repository in stainless-steel canisters, nominally 61 centimeters (24 inches) in diameter and either 3 or 4.5 meters (10 or 15 feet) in length, depending on the DOE site. The canister design specifications are contained in DIRS 101854-Marra, Harbour, and Plodinec (1995, all) and DIRS 103500-WVNS (n.d., WQR-2.2) for the operating vitrification processes at Savannah River Site and West Valley Demonstration Project, respectively. The other sites would use canister designs similar to those currently in use (DIRS 104406-Picha 1997, all).

These data were for analysis of the No-Action Alternative (see Chapter 7 and Appendix K) to determine the time required to breach the canisters after they are exposed to weather elements.

A.2 Materials

This section describes the characteristics of the materials DOE has considered for disposal in the proposed Yucca Mountain Repository. All candidate materials would have to meet approved acceptance criteria.

A.2.1 COMMERCIAL SPENT NUCLEAR FUEL

A.2.1.1 Background

Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation. Spent nuclear fuel from light-water reactors (pressurized-water and boiling-water reactors) would be the primary source of radioactivity and thermal load in the proposed monitored geologic repository. Spent nuclear fuels from civilian research reactors (General Atomics, Aerotest, etc.) account for less than 0.001 percent of the projected total in the Proposed Action (DIRS 104382-DOE 1995, all). The fuels addressed in this section are those discharged from commercial light-water reactors.

Section A.2.2 discusses the spent nuclear fuel from the Fort St. Vrain reactor in Colorado as part of DOE spent nuclear fuels, as are the fuels from Shippingport, Three Mile Island-2, and other fuels from commercial facilities that DOE has taken title to and is managing at its facilities.

A.2.1.2 Sources

The sources of commercial spent nuclear fuel are the commercial nuclear powerplants throughout the country. Table A-3 lists the individual reactors, reactor type, state, and actual or projected years of operation. The operating periods reflect six plants that have recently been granted extensions to their operating licenses. As noted in the table, additional extensions could be forthcoming, which could extend some of the operating periods. The operation period is also subject to change if a utility shuts down early. For conservatism, the estimated inventory of commercial spent nuclear fuel in Modules 1 and 2 was derived from the Energy Information Administration's "high case" projections. The high case assumes that all currently operating nuclear powerplants would renew their operating licenses for an additional 10 years.

A.2.1.3 Present Status

Nuclear power reactors store spent nuclear fuel in spent fuel pools under U.S. Nuclear Regulatory Commission licenses, and they can combine that option with above-grade dry storage in an independent

Table A-3. Commercial nuclear power reactors in the United States and their projected years of operation.[a]

Unit name	Reactor type[b]	State	Operations period[c]	Unit name	Reactor type[b]	State	Operations period[c]
Arkansas Nuclear One 1[d]	PWR	AR	1974-2034	Millstone 2	PWR	CT	1975-2015
Arkansas Nuclear One 2	PWR	AR	1978-2018	Millstone 3	PWR	CT	1986-2025
Beaver Valley 1	PWR	PA	1976-2016	Monticello	BWR	MN	1971-2010
Beaver Valley 2	PWR	PA	1978-2018	Nine Mile Point 1	BWR	NY	1969-2009
Big Rock Point	BWR	MI	1963-1997	Nine Mile Point 2	BWR	NY	1987-2026
Braidwood 1	PWR	IL	1987-2026	North Anna 1	PWR	VA	1978-2018
Braidwood 2	PWR	IL	1988-2027	North Anna 2	PWR	VA	1980-2020
Browns Ferry 1	BWR	AL	1973-2013	Oconee 1[d]	PWR	SC	1973-2033
Browns Ferry 2	BWR	AL	1974-2014	Oconee 2[d]	PWR	SC	1973-2033
Browns Ferry 3	BWR	AL	1976-2016	Oconee 3[d]	PWR	SC	1974-2034
Brunswick 1	BWR	NC	1976-2016	Oyster Creek	BWR	NJ	1969-2009
Brunswick 2	BWR	NC	1974-2014	Palisades	PWR	MI	1972-2007
Byron 1	PWR	IL	1985-2024	Palo Verde 1	PWR	AZ	1985-2024
Byron 2	PWR	IL	1987-2026	Palo Verde 2	PWR	AZ	1986-2025
Callaway	PWR	MO	1984-2024	Palo Verde 3	PWR	AZ	1987-2027
Calvert Cliffs 1[d]	PWR	MD	1974-2034	Peach Bottom 2	BWR	PA	1973-2013
Calvert Cliffs 2[d]	PWR	MD	1976-2036	Peach Bottom 3	BWR	PA	1974-2014
Catawba 1	PWR	SC	1985-2024	Perry 1	BWR	OH	1986-2026
Catawba 2	PWR	SC	1986-2026	Pilgrim 1	BWR	MA	1972-2012
Clinton	BWR	IL	1987-2026	Point Beach 1	PWR	WI	1970-2010
Comanche Peak 1	PWR	TX	1990-2030	Point Beach 2	PWR	WI	1973-2013
Comanche Peak 2	PWR	TX	1993-2033	Prairie Island 1	PWR	MN	1974-2013
Cooper Station	BWR	NE	1974-2014	Prairie Island 2	PWR	MN	1974-2014
Crystal River 3	PWR	FL	1977-2016	Quad Cities 1	BWR	IL	1972-2012
D. C. Cook 1	PWR	MI	1974-2014	Quad Cities 2	BWR	IL	1972-2012
D. C. Cook 2	PWR	MI	1977-2017	Rancho Seco	PWR	CA	1974-1989
Davis-Besse	PWR	OH	1977-2017	River Bend 1	BWR	LA	1985-2025
Diablo Canyon 1	PWR	CA	1984-2021	Salem 1	PWR	NJ	1976-2016
Diablo Canyon 2	PWR	CA	1985-2025	Salem 2	PWR	NJ	1981-2020
Dresden 1	BWR	IL	1959-1978	San Onofre 1	PWR	CA	1967-1992
Dresden 2	BWR	IL	1969-2006	San Onofre 2	PWR	CA	1982-2013
Dresden 3	BWR	IL	1971-2011	San Onofre 3	PWR	CA	1983-2013
Duane Arnold 1	BWR	IA	1974-2014	Seabrook 1	PWR	NH	1990-2026
Edwin I. Hatch 1	BWR	GA	1974-2014	Sequoyah 1	PWR	TN	1980-2020
Edwin I. Hatch 2	BWR	GA	1978-2018	Sequoyah 2	PWR	TN	1981-2021
Fermi 2	BWR	MI	1985-2025	Shearon Harris	PWR	NC	1987-2026
Fort Calhoun 1	PWR	NE	1973-2013	South Texas Project 1	PWR	TX	1988-2016
Ginna	PWR	NY	1969-2009	South Texas Project 2	PWR	TX	1989-2023
Grand Gulf 1	BWR	MS	1984-2022	St. Lucie 1	PWR	FL	1976-2016
Haddam Neck	PWR	CT	1968-1996	St. Lucie 2	PWR	FL	1983-2023
Hope Creek	BWR	NJ	1986-2026	Summer 1	PWR	SC	1982-2022
Humboldt Bay	BWR	CA	1962-1976	Surry 1	PWR	VA	1972-2012
H.B. Robinson 2	PWR	SC	1970-2010	Surry 2	PWR	VA	1973-2013
Indian Point 1	PWR	NY	1962-1974	Susquehanna 1	BWR	PA	1982-2022
Indian Point 2	PWR	NY	1973-2013	Susquehanna 2	BWR	PA	1984-2024
Indian Point 3	PWR	NY	1976-2015	Three Mile Island 1	PWR	PA	1974-2014
James A. FitzPatrick/ Nine Mile Point	BWR	NY	1974-2014	Trojan	PWR	OR	1975-1992
				Turkey Point 3	PWR	FL	1972-2012
Joseph M. Farley 1	PWR	AL	1977-2017	Turkey Point 4	PWR	FL	1973-2013
Joseph M. Farley 2	PWR	AL	1981-2021	Vermont Yankee	BWR	VT	1973-2012
Kewaunee	PWR	WI	1973-2013	Vogtle 1	PWR	GA	1987-2027
LaCrosse	BWR	WI	1967-1987	Vogtle 2	PWR	GA	1989-2029
LaSalle 1	BWR	IL	1970-2022	Columbia Generating Station	BWR	WA	1984-2023
LaSalle 2	BWR	IL	1970-2023				
Limerick 1	BWR	PA	1985-2024	Waterford 3	PWR	LA	1985-2024
Limerick 2	BWR	PA	1989-2029	Watts Bar 1	PWR	TN	1996-2035
Maine Yankee	PWR	ME	1972-1996	Wolf Creek	PWR	KS	1985-2025
McGuire 1	PWR	NC	1981-2021	Yankee-Rowe	PWR	MA	1963-1991
McGuire 2	PWR	NC	1983-2023	Zion 1	PWR	IL	1973-1997
Millstone 1	BWR	CT	1970-2010	Zion 2	PWR	IL	1974-1996

a. Source: DIRS 103493-DOE (1997, Appendix C).
b. PWR = pressurized-water reactor; BWR = boiling-water reactor.
c. As defined by current shutdown or full operation through license period (as of 1997), except as noted in Footnote d.
d. These plants have recently been granted 20-year operating license extensions. Several additional plants have applied for operating license extensions, and others could do so in the future.

spent fuel storage installation. When a reactor is refueled, spent fuel is transferred to the spent fuel pool, where it typically remains until the available pool capacity is reached. When in-pool storage capacity has been fully used, utilities have turned to dry cask storage in an independent spent fuel storage installation to expand their onsite spent fuel storage capacities. In 1990, the Nuclear Regulatory Commission amended its regulations to authorize licensees to store spent nuclear fuel at reactor sites in approved storage casks (DIRS 101913-Raddatz and Waters 1996, all).

Commercial nuclear utilities currently use three Nuclear Regulatory Commission-approved general dry storage system design types—metal storage casks and metal canisters housed in either concrete casks or concrete vaults—for use in licensed independent spent fuel storage installations. Raddatz and Waters (DIRS 101913-1996, all) contains detailed information on models currently approved by the Commission. Table A-4 lists the numbers of existing and planned at-reactor independent spent fuel storage installations in the United States as of 2001.

Table A-4. Sites with existing or planned independent spent fuel storage installations.[a]

Installations	Number
Existing	18
Planned	15

a. Sources: DIRS 155604-Delligatti (2001, all).

A.2.1.4 Final Spent Nuclear Fuel Form

The final form of commercial spent nuclear fuel to be disposed of in the proposed repository would be the spent reactor fuel assemblies. The repository would receive bare spent nuclear fuel assemblies, spent nuclear fuel packaged in canisters not intended for disposal, and spent nuclear fuel packaged in canisters intended for disposal.

A.2.1.5 Spent Nuclear Fuel Characteristics

There are 22 classes of nuclear fuel assemblies, with 127 individual fuel types in those classes. Seventeen of the classes are for pressurized-water reactor fuels and 5 are for boiling-water reactors (DIRS 102588-DOE 1992, Appendix 2A). For this EIS, the assemblies chosen for analysis represent an assembly type being used in the more recently built reactors. This results in physical characteristics that provide a realistic estimate for EIS analyses. Specifically chosen to represent the fuel types were the Westinghouse 17 × 17 LOPAR fuel assembly for the pressurized-water reactor and the General Electric BWR/4-6, 8 × 8 fuel assembly for the boiling-water reactor. Table A-5 lists the fissile content and performance parameters selected to define the radiological characteristics of these fuel assemblies. These parameters represent the average values for pressurized-water reactor and boiling-water reactor fuel to be received at the proposed repository.

Table A-5. Average spent nuclear fuel parameters.[a]

Fuel type[b]	Burnup (MWd/MTHM)[c]	Initial enrichment (percent of U-235 by weight)	Age (years)
Average PWR	41,200	3.75	23
Average BWR	33,600	3.03	23

a. Source: DIRS 153849-DOE (2001, p. 3-13).
b. PWR = pressurized-water reactor; BWR = boiling-water reactor.
c. MWd/MTHM = megawatt-days per metric ton of heavy metal; to convert metric tons to tons, multiply by 1.1023.

In the Draft EIS, Appendix A, DOE used fuel characteristics similar to those in Table A-5 to estimate consequences from accidents during transportation and repository operations. Since the publication of the Draft EIS, there has been concern that the radionuclide inventories of these average fuel assemblies could underestimate the potential dose consequences of an accidental release. In particular, using the average age of fuel likely to be sent to the repository does not fully take into account the effects of exponential radioactive decay and dose potential from accidental releases as the fuel aged.

As a result of these considerations, DOE undertook an effort to evaluate characteristics of commercial pressurized-water and boiling-water reactor spent nuclear fuel assemblies that span the entire range and distribution of the assemblies that would be shipped to the repository (DIRS 156919-Ikenberry 2001, all). The object of the effort was to characterize pressurized-water and boiling-water reactor assemblies that would represent a median hazard over the entire spectrum of commercial spent nuclear fuel. The result of this effort is in Table A-6, which lists the representative fuel used for accident analyses in this Final EIS. The effort included consideration of both mixed oxide (see Section A.2.4.5.1) as well as the bounding fuel types (highest burnup with lowest cooling time).

Table A-6. Representative commercial spent nuclear fuel characteristics for accident analyses.[a]

Fuel type[b]	Burnup (MWd/MTHM)[c]	Initial enrichment (percent of U-235 by weight)	Age (years)
Representative PWR	50,000	4.5	15
Representative BWR	40,000	3.5	14

a. Source: DIRS 156919-Ikenberry (2001, all).
b. PWR = pressurized-water reactor; BWR = boiling-water reactor.
c. MWd/MTHM = megawatt-days per metric ton of heavy metal; to convert metric tons to tons, multiply by 1.1023.

A.2.1.5.1 *Mass and Volume*

As discussed in Section A.1, the Proposed Action includes 63,000 MTHM of commercial spent nuclear fuel. For the No-Action Alternative (continued storage) analysis, Table A-7 lists the distribution of this expected inventory by reactor site. The historic and projected spent nuclear fuel discharge and storage information in Table A-7 is consistent with the annual projections provided by the Energy Information Administration (DIRS 103493-DOE 1997, p. 32). The "1995 Actual" data presented in Table A-7 represents the amount of spent nuclear fuel stored at a particular site regardless of the reactor from which it was discharged. For analysis purposes, the table lists spent nuclear fuel currently stored at the General Electric Morris, Illinois, facility to be at Dresden, because these facilities are located near each other.

For analyses associated with the Proposed Action, the projected spent nuclear fuel from pressurized-water reactors comprises 65 percent of the 63,000 metric tons of heavy metal (DIRS 100265-CRWMS M&O 1997, p. A-2). The balance consists of spent nuclear fuel from boiling-water reactors. Using the nominal volume for the spent nuclear fuel assemblies described in Section A.2.1.5.5, the estimated volume of spent nuclear fuel in the Proposed Action, exclusive of packaging, is 29,000 cubic meters.

Section A.1 also discusses the additional inventory modules evaluated in this EIS. Inventory Modules 1 and 2 both include the maximum expected discharge inventory of commercial spent nuclear fuel. Table A-8 lists historic and projected amounts of spent nuclear fuel discharged from commercial reactors through 2046. The estimated unpackaged volume of spent nuclear fuel for these modules is approximately 47,000 cubic meters. For conservatism, these data were derived from the Energy Information Administration "high case" assumptions. The high case assumes that all currently operating nuclear units would renew their operating licenses for an additional 10 years (DIRS 103493-DOE 1997, p. 32).

A.2.1.5.2 *Amount and Nature of Radioactivity*

Spent nuclear fuel from commercial nuclear powerplants contains several hundred radionuclides when removed from the reactor. However, due to minor quantities, short half-lives, biological significance, and other factors, most of these are not important from a public health hazard standpoint. DOE has

Table A-7. Proposed Action spent nuclear fuel inventory (MTHM).[a]

Site	Fuel type[b]	1995 actual	1996-2011[c]	Total[d]	Equivalent assemblies	Site	Fuel type[b]	1995 actual	1996-2011[c]	Total[d]	Equivalent assemblies
Arkansas Nuclear One	PWR	643	466	1,109	2,526	Monticello	BWR	147	280	426	2,324
Beaver Valley	PWR	437	581	1,018	2,206	North Anna	PWR	570	613	1,184	2,571
Big Rock Point	BWR	44	14	58	439	Oconee	PWR	1,098	767	1,865	4,028
Braidwood	PWR	318	711	1,029	2,424	Oyster Creek	BWR	374	325	699	3,824
Browns Ferry	BWR	840	1,092	1,932	10,402	Palisades	PWR	338	247	585	1,473
Brunswick	Both	448	448	896	4,410	Palo Verde	PWR	556	1,118	1,674	4,082
Byron	PWR	404	664	1,068	2,515	Peach Bottom	BWR	908	645	1,554	8,413
Callaway	PWR	280	422	702	1,609	Perry	BWR	178	274	452	2,470
Calvert Cliffs	PWR	641	501	1,142	2,982	Pilgrim	BWR	326	201	527	2,853
Catawba	PWR	465	683	1,148	2,677	Point Beach	PWR	529	347	876	2,270
Clinton	BWR	174	303	477	2,588	Prairie Island	PWR	518	348	866	2,315
Comanche Peak	PWR	176	821	998	2,202	Quad Cities	BWR	813	464	1,277	6,953
Cooper	BWR	175	277	452	2,435	Rancho Seco	PWR	228	--[e]	228	493
Crystal River	PWR	280	232	512	1,102	River Bend	BWR	176	356	531	2,889
D. C. Cook	PWR	777	656	1,433	3,253	Salem/Hope Creek	Both	793	866	1,659	7,154
Davis-Besse	PWR	243	262	505	1,076	San Onofre	PWR	722	701	1,423	3,582
Diablo Canyon	PWR	463	664	1,126	2,512	Seabrook	PWR	133	292	425	918
Dresden	BWR	1,557	590	2,146	11,602	Sequoyah	PWR	452	570	1,023	2,218
Duane Arnold	BWR	258	208	467	2,545	Shearon Harris	Both	498	252	750	2,499
Edwin I. Hatch	BWR	755	692	1,446	7,862	South Texas Project	PWR	290	722	1,012	1,871
Fermi	BWR	155	368	523	2,898	St. Lucie	PWR	601	419	1,020	2,701
Fort Calhoun	PWR	222	157	379	1,054	Summer	PWR	225	301	526	1,177
Ginna	PWR	282	180	463	1,234	Surry	PWR	660	534	1,194	2,604
Grand Gulf	BWR	349	506	856	4,771	Susquehanna	BWR	628	648	1,276	7,172
H. B. Robinson	PWR	145	239	384	903	Three Mile Island	PWR	311	236	548	1,180
Haddam Neck	PWR	355	65	420	1,017	Trojan	PWR	359	--	359	780
Humboldt Bay	BWR	29	--	29	390	Turkey Point	PWR	616	458	1,074	2,355
Indian Point	PWR	678	486	1,164	2,649	Vermont Yankee	BWR	387	222	609	3,299
James A. FitzPatrick/ Nine Mile Point	BWR	882	930	1,812	9,830	Vogtle	PWR	335	745	1,080	2,364
						Columbia Generating Station	BWR	243	338	581	3,223
Joseph M. Farley	PWR	644	530	1,174	2,555						
Kewaunee	PWR	282	169	451	1,172						
La Crosse	BWR	38	--	38	333	Waterford	PWR	253	247	500	1,217
La Salle	BWR	465	487	952	5,189	Watts Bar	PWR	--	251	251	544
Limerick	BWR	432	711	1,143	6,203	Wolf Creek	PWR	226	404	630	1,360
Maine Yankee	PWR	454	82	536	1,421	Yankee-Rowe	PWR	127	--	127	533
McGuire	PWR	714	725	1,439	3,257	Zion	PWR	841	211	1,052	2,302
Millstone	Both	959	749	1,709	6,447	***Totals***		***31,926***	***31,074***	***63,000***	***218,700***

a. Source: DIRS 155725-CRWMS M&O (1998, all).
b. PWR = pressurized-water reactor; BWR = boiling-water reactor.
c. Projected.
d. To convert metric tons to tons, multiply by 1.1023.
e. -- = no spent nuclear fuel production.

determined that 51 radionuclides represent all of the health-significant species that can contribute to a radiological dose if released in an accident. The derivation of the list of radionuclides of interest in terms of impacts to the public is described in Appendix H, Section H.2.1.4.1. Tables A-9 and A-10 list these radionuclides and their inventories for average pressurized-water and boiling-water reactor spent nuclear fuel assemblies. The inventories are presented at the average decay years for each of the assemblies.

Table A-11 combines the average inventories (curies per MTHM) with the projected totals (63,000 MTHM and 105,000 MTHM) to provide a total projected radionuclide inventory for the Proposed Action and additional modules.

Table A-8. Inventory Modules 1 and 2 spent nuclear fuel inventory (MTHM).[a]

Site	Fuel type[b]	1995 actual	1996-2046[c]	Total[d]	Equivalent assemblies
Arkansas Nuclear One	PWR	643	1,007	1,650	3,757
Beaver Valley	PWR	437	1,395	1,832	3,970
Big Rock Point	BWR	44	14	58	439
Braidwood	PWR	318	1,969	2,287	5,385
Browns Ferry	BWR	840	2,508	3,348	18,024
Brunswick	Both	448	992	1,440	7,355
Byron	PWR	404	1,777	2,181	5,139
Callaway	PWR	280	1,008	1,288	2,953
Calvert Cliffs	PWR	641	1,069	1,710	4,466
Catawba	PWR	465	1,752	2,217	5,168
Clinton	BWR	174	910	1,084	5,876
Comanche Peak	PWR	176	2,459	2,635	5,816
Cook	PWR	777	1,379	2,155	4,892
Cooper	BWR	175	587	762	4,106
Crystal River	PWR	280	525	805	1,734
Davis-Besse	PWR	243	582	825	1,757
Diablo Canyon	PWR	463	1,725	2,187	4,878
Dresden	BWR	1,557	984	2,541	13,740
Duane Arnold	BWR	258	434	692	3,776
Fermi	BWR	155	1,005	1,160	6,429
Fort Calhoun	PWR	222	312	534	1,485
Ginna	PWR	282	283	565	1,507
Grand Gulf	BWR	349	1,261	1,610	8,976
H. B. Robinson	PWR	145	364	509	1,197
Haddam Neck	PWR	355	65	420	1,017
Hatch	BWR	755	1,517	2,272	12,347
Humboldt Bay	BWR	29	--	29	390
Indian Point	PWR	678	1,005	1,683	3,787
James A. FitzPatrick/ Nine Mile Point	BWR	882	2,018	2,900	15,732
Joseph M. Farley	PWR	644	1,225	1,869	4,070
Kewaunee	PWR	282	330	612	1,591
La Crosse	BWR	38	--	38	333
La Salle	BWR	465	1,398	1,863	10,152
Limerick	BWR	432	1,958	2,390	12,967
Maine Yankee	PWR	454	82	536	1,421
McGuire	PWR	714	1,813	2,527	5,720
Millstone	Both	959	1,695	2,655	8,930

Site	Fuel type[b]	1995 actual	1996-2046[c]	Total[d]	Equivalent assemblies
Monticello	BWR	147	390	537	2,924
North Anna	PWR	570	1,384	1,955	4,246
Oconee	PWR	1,098	1,576	2,674	5,774
Oyster Creek	BWR	374	470	844	4,619
Palisades	PWR	338	395	733	1,845
Palo Verde	PWR	556	3,017	3,573	8,712
Peach Bottom	BWR	908	1,404	2,312	12,523
Perry	BWR	178	732	910	4,974
Point Beach	PWR	529	614	1,143	2,961
Prairie Island	PWR	518	692	1,210	3,234
Quad Cities	BWR	813	1,020	1,834	9,982
Pilgrim	BWR	326	444	770	4,170
Rancho Seco	PWR	228	--[e]	228	493
River Bend	BWR	176	956	1,132	6,153
Salem/Hope Creek	Both	793	2,452	3,245	11,584
San Onofre	PWR	722	1,321	2,043	5,144
Seabrook	PWR	133	831	964	2,083
Sequoyah	PWR	452	1,393	1,845	4,001
Shearon Harris	Both	498	707	1,205	3,535
South Texas Project	PWR	290	2,029	2,319	4,286
St. Lucie	PWR	601	1,010	1,611	4,265
Summer	PWR	225	732	958	2,141
Surry	PWR	660	1,029	1,689	3,682
Susquehanna	BWR	628	1,745	2,373	13,338
Three Mile Island	PWR	311	513	825	1,777
Trojan	PWR	359	--	359	780
Turkey Point	PWR	616	905	1,520	3,334
Vermont Yankee	BWR	387	434	822	4,451
Vogtle	PWR	335	2,122	2,458	5,378
Columbia Generating Station	BWR	243	924	1,167	6,476
Waterford	PWR	253	685	938	2,282
Watts Bar	PWR	--	893	893	1,937
Wolf Creek	PWR	226	1,052	1,278	2,759
Yankee-Rowe	PWR	127	--	127	533
Zion	PWR	841	211	1,052	2,302
Totals		***31,926***	***73,488***	***105,414***	***359,963***

a. Source: DIRS 155725-CRWMS M&O (1998, all).
b. PWR = pressurized-water reactor; BWR = boiling-water reactor.
c. Projected.
d. To convert metric tons to tons, multiply by 1.1023.
e. -- = no spent nuclear fuel production.

DOE used the fuel characteristics derived in Section A.2.1.5 and listed in Table A-6 to establish the fission product and radionuclide inventories of the pressurized-water and boiling-water reactor representative fuel assemblies used for accident analyses. For these analyses, DOE included a radionuclide contribution from activated corrosion products deposited on the surfaces of spent nuclear fuel assemblies during reactor operation. This material is called *crud*.

DOE used the fuel assembly surface concentration values in *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et. al. 2000, all) to develop the radioactive inventory from crud. The crud contains eight radionuclides. However, because all of these radionuclides except cobalt-60 decay rapidly, after storage (aging) for 5 years or longer, cobalt-60 is the only significant radionuclide remaining. The surface concentration values at discharge from the reactor range from 2 to 140 microcuries per square centimeter for pressurized-water reactor fuel assemblies and from 11 to 595 microcuries per square centimeter for boiling-water reactor assemblies, based on measurements of fuel rods (DIRS 152476-Sprung et al. 2000, p. 7-48; DIRS 103696-Sandoval 1991, all). Due to the wide range in concentration values and the limited number of measurements, DOE elected to use the maximum (cobalt-60) crud concentration numbers (DIRS 152476-Sprung et al. 2000, p. 7-48).

Table A-9. Radionuclide activity for average pressurized-water reactor fuel assemblies.[a,b]

Radionuclide[c]	Curies per assembly	Isotope	Curies per assembly	Isotope	Curies per assembly
Hydrogen-3	1.2×10^{2}	Antimony-125	2.6×10^{1}	Uranium-236	1.4×10^{-1}
Carbon-14	6.6×10^{-1}	Tin-126	4.5×10^{-1}	Uranium-238	1.4×10^{-1}
Chlorine-36	5.5×10^{-3}	Iodine-129	1.8×10^{-2}	Neptunium-237	2.4×10^{-1}
Iron-55	3.4×10^{0}	Cesium-134	4.4×10^{1}	Plutonium-238	1.9×10^{3}
Cobalt-60	2.2×10^{2}	Cesium-135	2.7×10^{-1}	Plutonium-239	1.8×10^{2}
Nickel-59	1.3×10^{0}	Cesium-137	3.4×10^{4}	Plutonium-240	2.8×10^{2}
Nickel-63	1.9×10^{2}	Promethium-147	1.3×10^{2}	Plutonium-241	2.4×10^{4}
Selenium-79	2.3×10^{-1}	Samarium-151	1.9×10^{2}	Plutonium-242	1.0×10^{0}
Krypton-85	1.1×10^{3}	Europium-154	9.6×10^{2}	Americium-241	1.6×10^{3}
Strontium-90	2.3×10^{4}	Europium-155	1.6×10^{2}	Americium-242/242m	1.1×10^{1}
Zirconium-93	1.2×10^{0}	Actinium-227	7.3×10^{-6}	Americium-243	1.4×10^{1}
Niobium-93m	8.1×10^{-1}	Thorium-230	1.4×10^{-4}	Curium-242	9.1×10^{0}
Niobium-94	6.0×10^{-1}	Protactinium-231	1.6×10^{-5}	Curium-243	9.7×10^{0}
Technetium-99	7.3×10^{0}	Uranium-232	2.1×10^{-2}	Curium-244	9.0×10^{2}
Ruthenium-106	3.3×10^{-2}	Uranium-233	3.1×10^{-5}	Curium-245	2.1×10^{-1}
Palladium-107	6.6×10^{-2}	Uranium-234	6.5×10^{-1}	Curium-246	4.7×10^{-2}
Cadmium-113m	1.1×10^{1}	Uranium-235	8.0×10^{-3}		

a. Source: DIRS 150276-CRWMS M&O (2000, p. VIII-3).
b. Burnup = 41,200 MWd/MTHM, enrichment = 3.75 percent, decay time = 23 years.
c. Half-lives are listed in Table A-11.

Table A-10. Radionuclide activity for average boiling-water reactor fuel assemblies.[a,b]

Radionuclide[c]	Curies per assembly	Isotope	Curies per assembly	Isotope	Curies per assembly
Hydrogen-3	4.2×10^{1}	Antimony-125	1.1×10^{1}	Uranium-236	4.5×10^{-2}
Carbon-14	2.9×10^{-1}	Tin-126	1.5×10^{-1}	Uranium-238	5.7×10^{-2}
Chlorine-36	2.1×10^{-3}	Iodine-129	6.1×10^{-3}	Neptunium-237	7.1×10^{-2}
Iron-55	9.5×10^{-1}	Cesium-134	1.6×10^{1}	Plutonium-238	6.0×10^{2}
Cobalt-60	6.5×10^{1}	Cesium-135	9.9×10^{-2}	Plutonium-239	6.0×10^{1}
Nickel-59	3.4×10^{-1}	Cesium-137	1.1×10^{4}	Plutonium-240	9.3×10^{1}
Nickel-63	4.5×10^{1}	Promethium-147	4.9×10^{1}	Plutonium-241	8.9×10^{3}
Selenium-79	7.7×10^{-2}	Samarium-151	6.6×10^{1}	Plutonium-242	4.0×10^{-1}
Krypton-85	3.7×10^{2}	Europium-154	3.2×10^{2}	Americium-241	6.1×10^{2}
Strontium-90	7.5×10^{3}	Europium-155	5.7×10^{1}	Americium-242/242m	4.7×10^{0}
Zirconium-93	4.6×10^{-1}	Actinium-227	2.6×10^{-6}	Americium-243	5.2×10^{0}
Niobium-93m	3.1×10^{-1}	Thorium-230	4.5×10^{-5}	Curium-242	3.9×10^{0}
Niobium-94	1.9×10^{-2}	Protactinium-231	5.4×10^{-6}	Curium-243	3.8×10^{0}
Technetium-99	2.4×10^{0}	Uranium-232	6.2×10^{-3}	Curium-244	3.5×10^{2}
Ruthenium-106	1.4×10^{-2}	Uranium-233	9.1×10^{-6}	Curium-245	7.9×10^{-2}
Palladium-107	2.4×10^{-2}	Uranium-234	2.1×10^{-1}	Curium-246	1.7×10^{-2}
Cadmium-113m	4.0×10^{0}	Uranium-235	2.6×10^{-3}		

a. Source: DIRS 150276-CRWMS M&O (2000, p. VIII-5).
b. Burnup = 33,600 MWd/MTHM, enrichment = 3.03 percent, decay time = 23 years.
c. Half-lives are listed in Table A-11.

Table A-11. Total projected radionuclide inventories[a,b] (page 1 of 2).

		Pressurized-water reactor			Boiling-water reactor				
			Total curies			Total curies		Grand totals (curies)	
Isotope	Half life (yrs.)[c]	Curies per MTHM[d]	Proposed Action	Additional modules	Curies per MTHM	Proposed Action	Additional modules	Proposed Action	Additional modules
Hydrogen-3	12.3	2.5×10^{2}	1.0×10^{7}	1.7×10^{7}	2.3×10^{2}	5.1×10^{6}	8.5×10^{6}	1.6×10^{7}	2.6×10^{7}
Carbon-14	5.7×10^{3}	1.4×10^{0}	5.9×10^{4}	9.8×10^{4}	1.6×10^{0}	3.6×10^{4}	6.0×10^{4}	9.5×10^{4}	1.6×10^{5}
Chlorine-36	3.0×10^{5}	1.2×10^{-2}	4.9×10^{2}	8.2×10^{2}	1.2×10^{-2}	2.6×10^{2}	4.3×10^{2}	7.5×10^{2}	1.2×10^{3}
Iron-55	2.7	7.4×10^{0}	3.0×10^{5}	5.1×10^{5}	5.3×10^{0}	1.2×10^{5}	1.9×10^{5}	4.2×10^{5}	7.0×10^{5}
Cobalt-60	5.3	4.7×10^{2}	1.9×10^{7}	3.2×10^{7}	3.6×10^{2}	8.0×10^{6}	1.3×10^{7}	2.7×10^{7}	4.5×10^{7}
Nickel-59	7.6×10^{4}	2.9×10^{0}	1.2×10^{5}	2.0×10^{5}	1.9×10^{0}	4.1×10^{4}	6.9×10^{4}	1.6×10^{5}	2.7×10^{5}
Nickel-63	1.0×10^{2}	4.0×10^{2}	1.7×10^{7}	2.8×10^{7}	2.5×10^{2}	5.5×10^{6}	9.2×10^{6}	2.2×10^{7}	3.7×10^{7}
Selenium-79	6.5×10^{4}	5.1×10^{-1}	2.1×10^{4}	3.5×10^{4}	4.3×10^{-1}	9.4×10^{3}	1.6×10^{4}	3.0×10^{4}	5.0×10^{4}
Krypton-85	10.7	2.5×10^{3}	1.0×10^{8}	1.7×10^{8}	2.1×10^{3}	4.6×10^{7}	7.6×10^{7}	1.5×10^{8}	2.5×10^{8}
Strontium-90	29	5.1×10^{4}	2.1×10^{9}	3.5×10^{9}	4.2×10^{4}	9.2×10^{8}	1.5×10^{9}	3.0×10^{9}	5.0×10^{9}
Zirconium-93	1.5×10^{6}	2.6×10^{0}	1.1×10^{5}	1.8×10^{5}	2.6×10^{0}	5.7×10^{4}	9.5×10^{4}	1.6×10^{5}	2.7×10^{5}
Niobium-93m	16	1.8×10^{0}	7.2×10^{4}	1.2×10^{5}	1.7×10^{0}	3.9×10^{4}	6.4×10^{4}	1.1×10^{5}	1.8×10^{5}
Niobium-94	2.4×10^{4}	1.3×10^{0}	5.3×10^{4}	8.9×10^{4}	1.1×10^{-1}	2.3×10^{3}	3.9×10^{3}	5.6×10^{4}	9.3×10^{4}
Technetium-99	2.1×10^{5}	1.6×10^{1}	6.5×10^{5}	1.1×10^{6}	1.4×10^{1}	3.0×10^{5}	5.0×10^{5}	9.5×10^{5}	1.6×10^{6}
Ruthenium-106	1.0	7.2×10^{-2}	3.0×10^{3}	4.9×10^{3}	7.9×10^{-2}	1.8×10^{3}	2.9×10^{3}	4.7×10^{3}	7.9×10^{3}
Palladium-107	6.5×10^{6}	1.4×10^{-1}	5.9×10^{3}	9.8×10^{3}	1.3×10^{-1}	2.9×10^{3}	4.8×10^{3}	8.8×10^{3}	1.5×10^{4}
Cadmium-113m	14	2.5×10^{1}	1.0×10^{6}	1.7×10^{6}	2.2×10^{1}	4.9×10^{5}	8.1×10^{5}	1.5×10^{6}	2.5×10^{6}
Antimony-125	2.8	5.6×10^{1}	2.3×10^{6}	3.9×10^{6}	5.9×10^{1}	1.3×10^{6}	2.2×10^{6}	3.6×10^{6}	6.0×10^{6}
Tin-126	1.0×10^{6}	9.8×10^{-1}	4.0×10^{4}	6.7×10^{4}	8.5×10^{-1}	1.9×10^{4}	3.1×10^{4}	5.9×10^{4}	9.8×10^{4}
Iodine-129	1.7×10^{7}	3.9×10^{-2}	1.6×10^{3}	2.7×10^{3}	3.4×10^{-2}	7.5×10^{2}	1.2×10^{3}	2.4×10^{3}	3.9×10^{3}
Cesium-134	2.1	9.5×10^{1}	3.9×10^{6}	6.5×10^{6}	8.7×10^{1}	1.9×10^{6}	3.2×10^{6}	5.8×10^{6}	9.7×10^{6}
Cesium-135	2.3×10^{6}	5.8×10^{-1}	2.4×10^{4}	3.9×10^{4}	5.5×10^{-1}	1.2×10^{4}	2.0×10^{4}	3.6×10^{4}	6.0×10^{4}
Cesium-137	30	7.5×10^{4}	3.1×10^{9}	5.1×10^{9}	6.4×10^{4}	1.4×10^{9}	2.3×10^{9}	4.5×10^{9}	7.4×10^{9}
Promethium-147	2.6	2.8×10^{2}	1.2×10^{7}	1.9×10^{7}	2.7×10^{2}	6.0×10^{6}	1.0×10^{7}	1.8×10^{7}	2.9×10^{7}
Samarium-151	90	4.2×10^{2}	1.7×10^{7}	2.9×10^{7}	3.7×10^{2}	8.1×10^{6}	1.4×10^{7}	2.5×10^{7}	4.2×10^{7}
Europium-154	8.6	2.1×10^{3}	8.5×10^{7}	1.4×10^{8}	1.8×10^{3}	3.9×10^{7}	6.5×10^{7}	1.2×10^{8}	2.1×10^{8}
Europium-155	4.8	3.6×10^{2}	1.5×10^{7}	2.4×10^{7}	3.2×10^{2}	7.0×10^{6}	1.2×10^{7}	2.2×10^{7}	3.6×10^{7}
Actinium-227	2.2	1.6×10^{-5}	6.5×10^{-1}	1.1×10^{0}	1.4×10^{-5}	3.1×10^{-1}	5.2×10^{-1}	9.7×10^{-1}	1.6×10^{0}
Thorium-230	7.5×10^{4}	3.0×10^{-4}	1.2×10^{1}	2.0×10^{1}	2.5×10^{-4}	5.5×10^{0}	9.1×10^{0}	1.8×10^{1}	2.9×10^{1}
Protactinium-231	3.3×10^{4}	3.4×10^{-5}	1.4×10^{0}	2.3×10^{0}	3.0×10^{-5}	6.7×10^{-1}	1.1×10^{0}	2.1×10^{0}	3.4×10^{0}
Uranium-232	69	4.5×10^{-2}	1.9×10^{3}	3.1×10^{3}	3.4×10^{-2}	7.5×10^{2}	1.3×10^{3}	2.6×10^{3}	4.3×10^{3}
Uranium-233	1.6×10^{5}	6.8×10^{-5}	2.8×10^{0}	4.7×10^{0}	5.1×10^{-5}	1.1×10^{0}	1.9×10^{0}	3.9×10^{0}	6.5×10^{0}
Uranium-234	2.5×10^{5}	1.4×10^{0}	5.8×10^{4}	9.6×10^{4}	1.2×10^{0}	2.6×10^{4}	4.3×10^{4}	8.4×10^{4}	1.4×10^{5}

Table A-11. Total projected radionuclide inventories[a,b] (page 1 of 2).

		Pressurized-water reactor			Boiling-water reactor			Grand totals (curies)	
			Total curies			Total curies			
Isotope	Half life (yrs.)[c]	Curies per MTHM[d]	Proposed Action	Additional modules	Curies per MTHM	Proposed Action	Additional modules	Proposed Action	Additional modules
Uranium-235	7.0×10^{8}	1.7×10^{-2}	7.1×10^{2}	1.2×10^{3}	1.4×10^{-2}	3.2×10^{2}	5.3×10^{2}	1.0×10^{3}	1.7×10^{3}
Uranium-236	2.3×10^{7}	3.1×10^{-1}	1.3×10^{4}	2.1×10^{4}	2.5×10^{-1}	5.5×10^{3}	9.1×10^{3}	1.8×10^{4}	3.0×10^{4}
Uranium-238	4.5×10^{9}	3.1×10^{-1}	1.3×10^{4}	2.1×10^{4}	3.2×10^{-1}	7.0×10^{3}	1.2×10^{4}	2.0×10^{4}	3.3×10^{4}
Neptunium-237	2.1×10^{6}	5.2×10^{-1}	2.1×10^{4}	3.5×10^{4}	4.0×10^{-1}	8.7×10^{3}	1.5×10^{4}	3.0×10^{4}	5.0×10^{4}
Plutonium-238	88	4.1×10^{3}	1.7×10^{8}	2.8×10^{8}	3.3×10^{3}	7.4×10^{7}	1.2×10^{8}	2.4×10^{8}	4.0×10^{8}
Plutonium-239	2.4×10^{4}	4.0×10^{2}	1.6×10^{7}	2.7×10^{7}	3.3×10^{2}	7.3×10^{6}	1.2×10^{7}	2.4×10^{7}	4.0×10^{7}
Plutonium-240	6.5×10^{3}	6.0×10^{2}	2.5×10^{7}	4.1×10^{7}	5.2×10^{2}	1.1×10^{7}	1.9×10^{7}	3.6×10^{7}	6.0×10^{7}
Plutonium-241	14	5.2×10^{4}	2.1×10^{9}	3.5×10^{9}	5.0×10^{4}	1.1×10^{9}	1.8×10^{9}	3.2×10^{9}	5.3×10^{9}
Plutonium-242	3.8×10^{5}	2.2×10^{0}	9.2×10^{4}	1.5×10^{5}	2.2×10^{0}	4.9×10^{4}	8.2×10^{4}	1.4×10^{5}	2.3×10^{5}
Americium-241	4.3×10^{2}	3.6×10^{3}	1.5×10^{8}	2.4×10^{8}	3.4×10^{3}	7.4×10^{7}	1.2×10^{8}	2.2×10^{8}	3.7×10^{8}
Americium-242/242m	1.4×10^{2}	2.4×10^{1}	9.8×10^{5}	1.6×10^{6}	2.6×10^{1}	5.7×10^{5}	9.5×10^{5}	1.6×10^{6}	2.6×10^{6}
Americium-243	7.4×10^{3}	3.0×10^{1}	1.2×10^{6}	2.0×10^{6}	2.9×10^{1}	6.4×10^{5}	1.1×10^{6}	1.9×10^{6}	3.1×10^{6}
Curium-242	0.45	2.0×10^{1}	8.1×10^{5}	1.4×10^{6}	2.1×10^{1}	4.7×10^{5}	7.9×10^{5}	1.3×10^{6}	2.1×10^{6}
Curium-243	29	2.1×10^{1}	8.6×10^{5}	1.4×10^{6}	2.1×10^{1}	4.6×10^{5}	7.7×10^{5}	1.3×10^{6}	2.2×10^{6}
Curium-244	18	1.9×10^{3}	8.0×10^{7}	1.3×10^{8}	1.9×10^{3}	4.3×10^{7}	7.1×10^{7}	1.2×10^{8}	2.0×10^{8}
Curium-245	8.5×10^{3}	4.6×10^{-1}	1.9×10^{4}	3.2×10^{4}	4.4×10^{-1}	9.7×10^{3}	1.6×10^{4}	2.9×10^{4}	4.8×10^{4}
Curium-246	4.8×10^{3}	1.0×10^{-1}	4.2×10^{3}	7.0×10^{3}	9.5×10^{-2}	2.1×10^{3}	3.5×10^{3}	6.3×10^{3}	1.0×10^{4}

a. Source: Compilation of Tables A-9 and A-10.

b. The radionuclides listed are those used in the most recent repository preclosure safety assessment (DIRS 150276-CRWMS M&O 2000, all) and include all those used in the postclosure impacts analysis (Chapter 5). The radionuclides listed have been revised from the list in the Draft EIS; DOE has determined that the revisions to the list (including both omissions and additions) resulted in no change to the preclosure accident impacts.

c. Half-life is defined as the time in which half of the atoms of a radioactive substance decay to another nuclear form.

d. MTHM = metric tons of heavy metal; 0.18 MTHM per boiling-water reactor assembly and 0.46 MTHM per pressurized-water reactor assembly.

Converting the surface concentration values to total assembly inventory requires estimates of the surface area of the assembly. Conservative estimated surface area values for pressurized-water and boiling-water reactor assemblies currently in operation are 450,000 square centimeters (1,200 square feet) for pressurized-water reactor assemblies and 170,000 square centimeters (460 square feet) for boiling-water reactor assemblies (DIRS 150276-CRWMS M&O 2000, p. VIII-4, 5).

The resulting cobalt-60 crud inventories at discharge from the reactor, therefore, are 450,000 square centimeters × 140 microcuries per square centimeter = 63 curies for pressurized-water reactor assemblies and 170,000 square centimeters × 595 microcuries per square centimeter = 100 curies for boiling-water reactor assemblies. Because these values would be at the time of discharge of the fuel from the reactor, the inventories must be corrected for radioactive decay. The half-life (time for half of the radionuclide to decay) of cobalt-60 is 5.27 years. Because the representative fuel assemblies (see Table A-6) are 14 years old for boiling-water reactor fuel and 15 years old for pressurized-water reactor fuel, the cobalt-60 inventories must be reduced by 2.66 (14/5.27) half-lives for boiling-water reactor fuel and 2.85 (15/5.27) half-lives for the pressurized-water reactor fuel. The resulting inventories are then $100/(2)^{2.66}$ = 16 curies per boiling-water reactor assembly and $63/(2)^{2.85}$ = 9 curies per pressurized-water reactor assembly. Because DOE used maximum values for both the surface concentration and surface area, these results are conservative.

Tables A-12 and A-13 list the radionuclide inventories for the representative pressurized-water and boiling-water reactor spent nuclear fuel assemblies, respectively. The list of radionuclides is modified from DIRS 150276-CRWMS M&O (2000, p. VIII-3), which DOE used for preclosure accident analyses. For accident evaluation, the location of the radionuclides on and in the fuel assemblies can be important, so these tables provide this information (DIRS 152476-Sprung et al. 2000, all). Some of the radionuclides are produced by neutron activation of stable elements in the structures of the fuel assembly; these are listed in the Location column. A few radionuclides reside in the gap between the fuel pellet and the cladding; these are also listed in the Location column. The majority of the radionuclides are in the fuel pellets, as listed in the tables, and a few are in both the fuel pellet and the fuel clad gap.

A.2.1.5.3 *Chemical Composition*

Commercial spent nuclear fuel consists of the uranium oxide fuel itself (including actinides, fission products, etc.), the cladding, and the assembly hardware.

Typical pressurized-water and boiling-water reactor fuels consist of uranium dioxide fuel pellets with a zirconium alloy cladding. Some assemblies, however, are clad in stainless-steel 304. These assemblies have been discharged from Haddam Neck, Yankee-Rowe, Indian Point, San Onofre, and LaCrosse and comprise 1.15 percent of the MTHM included in the Proposed Action. Table A-14 lists the number sites, storage locations, and fuel assemblies and MTHM discharged.

Tables A-15 and A-16 list the postirradiation elemental distributions for typical fuels. The data in these tables include the fuel, cladding material, and assembly hardware.

A.2.1.5.4 *Thermal Output*

Heat generation rates are available as a function of spent fuel type, enrichment, burnup, and decay time in the Light-Water Reactor Radiological Database, which is an integral part of the *Characteristics of Potential Repository Wastes* (DIRS 102588-DOE 1992, p. 1.1-1). Table A-17 lists the thermal profiles for the average pressurized-water reactor and boiling-water reactor assemblies from the Light-Water Reactor Radiological Database. For the EIS analysis, the typical thermal profile, applied across the proposed inventory, yields a good approximation of the expected thermal load in the repository. Figure A-6 shows these profiles as a function of time.

Table A-12. Radionuclide activity for representative pressurized-water reactor fuel assemblies.[a,b]

Radionuclide[c]	Curies per assembly	Location	Radionuclide[c]	Curies per assembly	Location
Hydrogen-3	2.0×10^{2}	Fuel clad gap	Samarium-151	2.4×10^{2}	Fuel pellet
Carbon-14	3.0×10^{-1}	Fuel clad gap	Europium-154	1.5×10^{3}	Fuel pellet
Chlorine-36	6.3×10^{-3}	Fuel clad gap	Europium-155	2.2×10^{2}	Fuel pellet
Iron-55	4.0×10^{1}	Structures	Actinium-227	1.3×10^{-5}	Fuel pellet
Cobalt-60	1.1×10^{3}	Structures	Thorium-230	9.9×10^{-5}	Fuel pellet
Cobalt-60	8.8×10^{0}	Surfaces (crud)	Protactinium-231	3.3×10^{-5}	Fuel pellet
Nickel-59	1.9×10^{0}	Structures	Uranium-232	2.4×10^{-2}	Fuel pellet
Nickel-63	2.5×10^{2}	Structures	Uranium-233	3.2×10^{-5}	Fuel pellet
Selenium-79	4.6×10^{-2}	Fuel pellet	Uranium-234	6.7×10^{-1}	Fuel pellet
Krypton-85	2.2×10^{3}	Fuel clad gap	Uranium-235	8.8×10^{-3}	Fuel pellet
Strontium-90	3.6×10^{4}	Fuel pellet, gap	Uranium-236	1.9×10^{-1}	Fuel pellet
Yttrium-90[d]	3.6×10^{4}	Fuel pellet, gap	Uranium-238	1.4×10^{-1}	Fuel pellet
Zirconium-93	9.8×10^{-1}	Fuel pellet	Neptunium-237	2.5×10^{-1}	Fuel pellet
Niobium-93m	1.9×10^{1}	Fuel pellet	Plutonium-238	2.6×10^{3}	Fuel pellet
Niobium-94	8.1×10^{-1}	Fuel pellet	Plutonium-239	1.8×10^{2}	Fuel pellet
Technetium-99	9.1×10^{0}	Fuel pellet	Plutonium-240	3.1×10^{2}	Fuel pellet
Ruthenium-106	1.1×10^{1}	Fuel pellet	Plutonium-241	3.9×10^{4}	Fuel pellet
Palladium-107	7.8×10^{-2}	Fuel pellet	Plutonium-242	1.5×10^{0}	Fuel pellet
Cadmium-113m	1.2×10^{1}	Fuel pellet	Americium-241	1.5×10^{3}	Fuel pellet
Tin-126	3.7×10^{-1}	Fuel pellet	Americium-242m	7.2×10^{0}	Fuel pellet
Antimony-125	1.2×10^{2}	Fuel pellet	Americium-243	2.0×10^{1}	Fuel pellet
Iodine-129	2.2×10^{-2}	Fuel clad gap	Curium-242	5.9×10^{0}	Fuel pellet
Cesium-134	7.2×10^{2}	Fuel pellet, gap	Curium-243	1.3×10^{1}	Fuel pellet
Cesium-135	3.8×10^{-1}	Fuel pellet, gap	Curium-244	1.8×10^{3}	Fuel pellet
Cesium-137	5.2×10^{4}	Fuel pellet, gap	Curium-245	2.9×10^{-1}	Fuel pellet
Barium-137m[d]	5.2×10^{4}	Fuel pellet, gap	Curium-246	9.1×10^{-2}	Fuel pellet
Promethium-147	1.7×10^{3}	Fuel pellet			

a. Source: DIRS 156919-Ikenberry (2001, all).
b. Burnup = 50,000 MWd/MTHM, enrichment = 4.3 percent, decay time = 15 years.
c. Half-lives are listed in Table A-11.
d. Barium-137m and yttrium-90 are included and are assumed to be in equilibrium with cesium-137 and strontium-90, respectively.

A.2.1.5.5 *Physical Parameters*

Table A-18 lists reference characteristics of typical pressurized-water and boiling-water reactor fuel assemblies. These data are from the Integrated Data Base Report (DIRS 101815-DOE 1997, p. 1-8) and reflect characteristics of unirradiated assemblies.

For additional details, the Light-Water Reactor Assembly Database contains individual physical descriptions of the fuel assemblies and fuel pins. The Light-Water Reactor Nonfuel Assembly Hardware Database contains physical and radiological descriptions of nonfuel assembly hardware. These databases are integral parts of the *Characteristics of Potential Repository Wastes* (DIRS 102588-DOE 1992, Section 2.8).

A.2.2 DOE SPENT NUCLEAR FUEL

A.2.2.1 Background

At present, DOE stores most of its spent nuclear fuel at three primary locations: the Hanford Site in Washington State, the Idaho National Engineering and Environmental Laboratory in Idaho, and the

Table A-13. Radionuclide activity for representative boiling-water reactor fuel assemblies.[a,b,c]

Radionuclide[c]	Curies per assembly	Location	Isotope	Curies per assembly	Location
Hydrogen-3	6.6×10^{1}	Fuel clad gap	Samarium-151	5.3×10^{1}	Fuel pellet
Carbon-14	1.6×10^{-1}	Fuel clad gap	Europium-154	3.9×10^{2}	Fuel pellet
Chlorine-36	2.6×10^{-3}	Fuel clad gap	Europium-155	7.5×10^{1}	Fuel pellet
Iron-55	1.6×10^{1}	Structures	Actinium-227	0	Fuel pellet
Cobalt-60	1.7×10^{2}	Structures	Thorium-230	3.3×10^{-5}	Fuel pellet
Cobalt-60	1.6×10^{1}	Surfaces (crud)	Protactinium-231	1.2×10^{-5}	Fuel pellet
Nickel-59	4.5×10^{-1}	Structures	Uranium-232	4.6×10^{-3}	Fuel pellet
Nickel-63	5.7×10^{1}	Structures	Uranium-233	0	Fuel pellet
Selenium-79	1.4×10^{-2}	Fuel pellet	Uranium-234	2.1×10^{-1}	Fuel pellet
Krypton-85	7.0×10^{2}	Fuel clad gap	Uranium-235	2.4×10^{-3}	Fuel pellet
Strontium-90	1.1×10^{4}	Fuel pellet, gap	Uranium-236	5.6×10^{-2}	Fuel pellet
Yttrium-90[d]	1.1×10^{4}	Fuel pellet, gap	Uranium-238	5.7×10^{-2}	Fuel pellet
Zirconium-93	3.0×10^{-1}	Fuel pellet	Neptunium-237	6.0×10^{-2}	Fuel pellet
Niobium-93m	5.0×10^{-1}	Fuel pellet	Plutonium-238	5.7×10^{-2}	Fuel pellet
Niobium-94	1.7×10^{-2}	Fuel pellet	Plutonium-239	4.8×10^{1}	Fuel pellet
Technetium-99	2.9×10^{0}	Fuel pellet	Plutonium-240	1.0×10^{3}	Fuel pellet
Ruthenium-106	4.9×10^{0}	Fuel pellet	Plutonium-241	1.0×10^{4}	Fuel pellet
Palladium-107	2.4×10^{-2}	Fuel pellet	Plutonium-242	4.6×10^{-1}	Fuel pellet
Cadmium-113m	3.5×10^{0}	Fuel pellet	Americium-241	3.7×10^{2}	Fuel pellet
Tin-126	1.1×10^{-1}	Fuel pellet	Americium-242m	2.1×10^{0}	Fuel pellet
Antimony-125	4.3×10^{1}	Fuel pellet	Americium-243	4.8×10^{0}	Fuel pellet
Iodine-129	6.7×10^{-3}	Fuel clad gap	Curium-242	1.7×10^{0}	Fuel pellet
Cesium-134	2.3×10^{2}	Fuel pellet, gap	Curium-243	2.9×10^{0}	Fuel pellet
Cesium-135	1.3×10^{-1}	Fuel pellet, gap	Curium-244	3.5×10^{2}	Fuel pellet
Cesium-137	1.6×10^{4}	Fuel pellet, gap	Curium-245	3.6×10^{-2}	Fuel pellet
Barium-137m[d]	1.6×10^{4}	Fuel pellet, gap	Curium-246	1.8×10^{-2}	Fuel pellet
Promethium-147	6.6×10^{2}	Fuel pellet			

a. Source: DIRS 156919-Ikenberry (2001, all).
b. Burnup = 40,000 MWd/MTHM, enrichment = 3.5 percent, decay time = 14 years.
c. Half-lives are listed in Table A-11.
d. Barium-137m and yttrium-90 are included and are assumed to be in equilibrium with cesium-137 and strontium-90, respectively.

Table A-14. Stainless-steel-clad spent nuclear fuel inventory.[a]

Discharging reactors	Storage locations	Assemblies	MTHM[b]
5	6	2,187	727

a. Source: DIRS 104353-Cole (1998, all).
b. MTHM = metric tons of heavy metal.

Savannah River Site in South Carolina. Some DOE spent nuclear fuel is stored at the Fort St. Vrain dry storage facility in Colorado. DOE issued the *Record of Decision – Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* on June 1, 1995 (DIRS 103205-DOE 1995, all) and amended it in March 1996 (DIRS 147933-DOE 1996, all). The Record of Decision and its amendment specify three primary locations as storage sites for DOE spent nuclear fuel. With the exception of Fort St. Vrain, which will retain its spent nuclear fuel in dry storage, DOE will ship all its spent nuclear fuel from other sites to one of the three primary sites for storage and preparation for ultimate disposition.

Table A-15. Elemental distribution of average pressurized-water reactor fuel.[a]

Element	Grams per assembly[b]	Percent total[c]	Element	Grams per assembly[b]	Percent total[c]
Aluminum	47	0.01	Oxygen	62,000	9.35
Americium	600	0.09	Palladium	790	0.12
Barium	1,200	0.18	Phosphorus	85	0.01
Cadmium	77	0.01	Plutonium	4,600	0.69
Carbon	77	0.01	Praseodymium	610	0.09
Cerium	1,300	0.20	Rhodium	230	0.04
Cesium	1,100	0.17	Rubidium	200	0.03
Chromium	4,300	0.65	Ruthenium	1,200	0.18
Cobalt	38	0.01	Samarium	470	0.07
Europium	72	0.01	Silicon	170	0.03
Gadolinium	81	0.01	Silver	40	0.01
Iodine	130	0.02	Strontium	330	0.05
Iron	12,000	1.85	Technetium	420	0.06
Krypton	190	0.03	Tellurium	270	0.04
Lanthanum	670	0.10	Tin	1,900	0.29
Manganese	330	0.05	Titanium	51	0.01
Molybdenum	2,000	0.31	Uranium	440,000	65.78
Neodymium	2,200	0.33	Xenon	2,900	0.43
Neptunium	330	0.05	Yttrium	250	0.04
Nickel	5,000	0.75	Zirconium	120,000	17.77
Niobium	330	0.05			
Nitrogen	49	0.01	***Totals***	***668,637***	***99.99***

a. Source: DIRS 102588-DOE (1992, p. 1.1-1).
b. To convert grams to ounces, multiply by 0.035274.
c. Table only includes elements that constitute at least 0.01 percent of the total; therefore, the total of the percentage column is slightly less than 100 percent.

During the last four decades, DOE and its predecessor agencies have generated approximately 250 varieties of spent nuclear fuel from weapons production, nuclear propulsion, and research missions. A method described by (DIRS 104385-Fillmore 1998, all) allows grouping of these many varieties of spent nuclear fuel into 16 categories for the repository Total System Performance Assessment. The grouping method uses regulatory requirements to identify the parameters that would affect the performance of DOE spent nuclear fuel in the repository and meet analysis needs for the repository License Application. Three fuel parameters (fuel matrix, fuel compound, and cladding condition) would influence repository performance behavior. The methodology categorizes the characteristics of a select number of fuel types either bound or represent a particular characteristic of the whole category. Table A-19 lists these spent nuclear fuel categories, which continue to provide an accurate description of the DOE fuel characteristics for this Final EIS (DIRS 156369-Arenaz 2001, all).

Table A-19 includes sodium-bonded fuel (Category 14). DOE issued a Record of Decision for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel in September 2000. Electrometallurgical treatment, the preferred alternative, was chosen for EBR-II reactor fuel and other selected small lots. Fermi blanket fuel may be treated by the electrometallurgical process but the final decision has been deferred. Section A.2.3, which covers data associated with high-level radioactive waste, includes data on waste produced from the treatment of all Category 14 spent nuclear fuel (DIRS 104356-Dirkmaat 1997, p. 7). Therefore, this category is not considered as spent nuclear fuel in the EIS.

Table A-16. Elemental distribution of average boiling-water reactor fuel.[a]

Element	Grams per assembly[b]	Percent total[c]	Element	Grams per assembly[b]	Percent total[c]
Aluminum	31	0.01	Nitrogen	25	0.01
Americium	220	0.07	Oxygen	25,000	7.82
Barium	390	0.12	Palladium	270	0.09
Cadmium	27	0.01	Plutonium	1,500	0.48
Carbon	36	0.01	Praseodymium	200	0.06
Cerium	430	0.14	Rhodium	79	0.03
Cesium	390	0.12	Rubidium	64	0.02
Chromium	1,900	0.60	Ruthenium	410	0.13
Cobalt	26	0.01	Samarium	160	0.05
Europium	24	0.01	Silicon	80	0.03
Gadolinium	310	0.10	Strontium	110	0.03
Iodine	43	0.01	Technetium	140	0.04
Iron	5,100	1.63	Tellurium	91	0.03
Krypton	62	0.02	Tin	1,600	0.50
Lanthanum	220	0.07	Titanium	83	0.03
Manganese	160	0.05	Uranium	170,000	55.35
Molybdenum	630	0.20	Xenon	950	0.30
Neodymium	730	0.23	Yttrium	81	0.03
Neptunium	97	0.03	Zirconium	96,000	30.52
Nickel	3,000	0.94			
Niobium	29	0.01	***Totals***	***310,698***	***99.94***

a. Source: DIRS 102588-DOE (1992, p. 1.1-1).
b. To convert grams to ounces, multiply by 0.035274.
c. Table only includes elements that contribute at least 0.01 percent of the total; therefore, the total of the percentage column is slightly less than 100 percent.

Table A-17. Average assembly thermal profiles.[a]

Years after discharge	Pressurized-water reactor		Boiling-water reactor	
	W/MTHM[b]	W/assembly[c]	W/MTHM	W/assembly[d]
1	10,500	4,800	8,400	1,500
3	3,700	1,700	3,000	550
5	2,200	1,000	1,800	340
10	1,500	670	1,200	220
25	990	450	820	150
30	920	420	770	140
50	670	310	570	100
100	370	170	320	58
300	160	73	140	26
500	120	53	100	19
1,000	66	31	58	11
2,000	35	16	30	5
5,000	22	10	19	3
10,000	16	8	13	3

a. Source: DIRS 102588-DOE (1992, p. 1.1-1).
b. W/MTHM = watts per metric ton of heavy metal; to convert metric tons to tons, multiply by 1.1023.
c. W/assembly = watts per assembly; assumes 0.46 MTHM per assembly.
d. Assumes 0.18 MTHM per assembly.

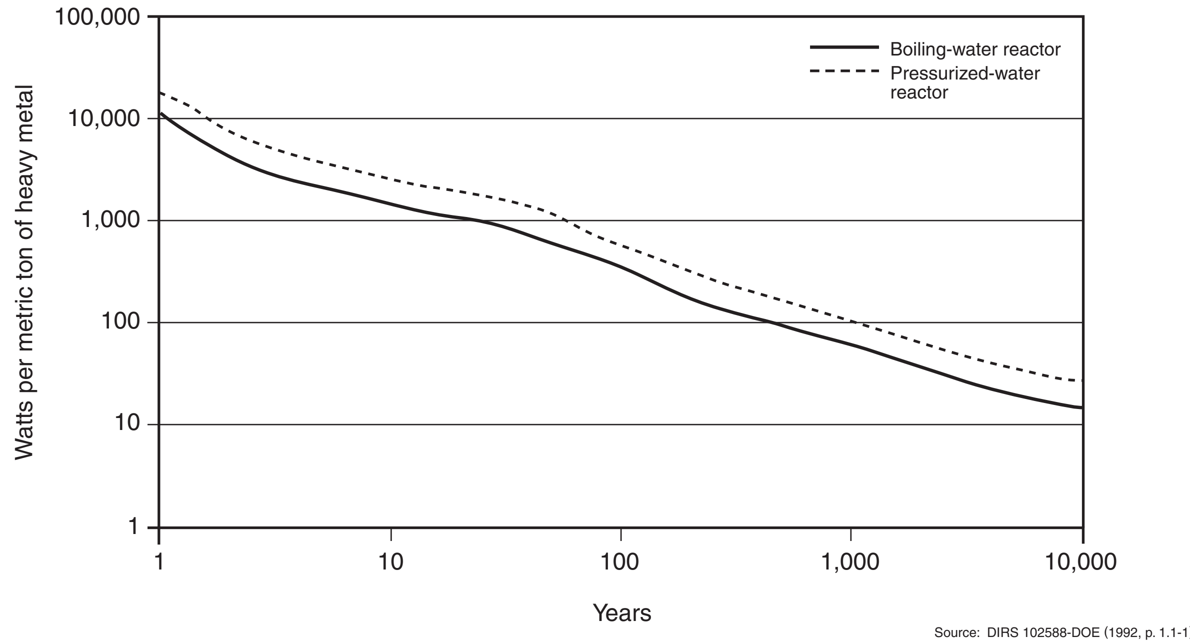


Figure A-6. Average thermal profiles over time.

Table A-18. Reference characteristics for average commercial spent nuclear fuel assemblies.[a]

Characteristics[b]	Boiling-water reactor	Pressurized-water reactor
Overall assembly length (meters)	4.5	4.1
Cross section (centimeters)	14 × 14	21 × 21
Fuel rod length (meters)	4.1	3.9
Active fuel height (meters)	3.8	3.7
Fuel rod outer diameter (centimeters)	1.3	0.95
Fuel rod array	8 × 8	17 × 17
Fuel rods per assembly	63	264
Assembly total weight (kilograms)	320	660
Uranium per assembly (kilograms)	180	460
Uranium oxide per assembly (kilograms)	210	520
Zirconium alloy per assembly (kilograms)	100[c]	110[d]
Hardware per assembly (kilograms)	8.6[e]	26[f]
Nominal volume per assembly (cubic meters)	0.086[g]	0.19[g]

a. Source: DIRS 101815-DOE (1997, p. 1-8).
b. To convert meters to feet, multiply by 3.2808; to convert centimeters to inches, multiply by 0.3937; to convert kilograms to pounds, multiply by 2.2046; to convert cubic meters to cubic feet, multiply by 35.314.
c. Includes zirconium alloy fuel rod spacers and fuel channels.
d. Includes zirconium alloy control rod guide thimbles.
e. Includes stainless-steel tie plates, Inconel springs, and plenum springs.
f. Includes stainless-steel nozzles and Inconel-718 grids.
g. Based on overall outside dimension; includes spacing between the stacked fuel rods of the assembly.

A.2.2.2 Sources

The DOE National Spent Fuel Program maintains a spent nuclear fuel data base (DIRS 153072-Wheatley 2000, all). Table A-19 provides a brief description of each of the fuel categories and a typical fuel. Section A.2.2.5.3 provides more detail on the chemical makeup of each category.

Table A-19. DOE spent nuclear fuel categories.[a,b,c]

	DOE SNF category	Typically from	Description of fuel
1.	Uranium metal	N-Reactor	Uranium metal fuel compounds with aluminum or zirconium alloy cladding
2.	Uranium-zirconium	HWCTR	Uranium alloy fuel compounds with zirconium alloy cladding
3.	Uranium-molybdenum	Fermi	Uranium-molybdenum alloy fuel compounds with zirconium alloy cladding
4.	Uranium oxide, intact	Commercial PWR	Uranium oxide fuel compounds with zirconium alloy or stainless-steel cladding in fair to good condition
5.	Uranium oxide, failed/ declad/aluminum clad	TMI core debris	Uranium oxide fuel compounds: (1) without cladding; (2) clad with zirconium alloy, Hastelloy, nickel-chromium, or stainless steel in poor or unknown condition; or (3) nondegraded aluminum clad
6.	Uranium-aluminide	ATR	Uranium-aluminum alloy fuel compounds with aluminum cladding
7.	Uranium-silicide	FRR MTR	Uranium silicide fuel compounds with aluminum cladding
8.	Thorium/uranium carbide, high-integrity	Fort St. Vrain	Thorium/uranium carbide fuel compounds with graphite cladding in good condition
9.	Thorium/uranium carbide, low-integrity	Peach Bottom	Thorium/uranium carbide fuel compounds with graphite cladding in unknown condition
10.	Plutonium/uranium carbide, nongraphite	FFTF carbide	Uranium carbide or plutonium-uranium carbide fuel compounds with or without stainless-steel cladding
11.	Mixed oxide	FFTF oxide	Plutonium/uranium oxide fuel compounds in zirconium alloy, stainless-steel, or unknown cladding
12.	Uranium/thorium oxide	Shippingport LWBR	Uranium/thorium oxide fuel compounds with zirconium alloy or stainless-steel cladding
13.	Uranium-zirconium hydride	TRIGA	Uranium-zirconium hydride fuel compounds with or without Incalloy, stainless-steel, or aluminum cladding
14.	Sodium-bonded	EBR-II driver and blanket, Fermi-I blanket	Uranium and uranium-plutonium metallic alloy with predominantly stainless-steel cladding
15.	Naval fuel	Surface ship/ submarine	Uranium-based with zirconium alloy cladding
16.	Miscellaneous	Not specified	Various fuel compounds with or without zirconium alloy, aluminum, Hastelloy, tantalum, niobium, stainless-steel or unknown cladding

a. Source: DIRS 104385-Fillmore (1998, all).
b. Abbreviations: SNF = spent nuclear fuel; HWCTR = heavy-water cooled test reactor; PWR = pressurized-water reactor; TMI = Three Mile Island; ATR = Advanced Test Reactor; FRR MTR = foreign research reactor – material test reactor; FFTF = Fast Flux Test Facility; LWBR = light-water breeder reactor; TRIGA = Training Research Isotopes—General Atomic; EBR-II = Experimental Breeder Reactor II.
c. For ongoing repository performance analyses, the 16 DOE fuel categories have been reduced to 11 categories (DIRS 118968-DOE 2000, all) since the publication of the Draft EIS. The reduction reflects a better understanding of the behavior of DOE fuels under repository conditions and allows the combining of some of the 16 DOE fuel categories. The reduced DOE fuel categories will help streamline future repository analyses of DOE fuels.

A.2.2.3 Present Storage and Generation Status

Table A-20 lists storage locations and inventory information on DOE spent nuclear fuels. During the preparation of the *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DIRS 101802-DOE 1995, all), DOE evaluated and categorized

Table A-20. National Spent Nuclear Fuel Database projection of DOE spent nuclear fuel locations and inventories to 2035.[a,b]

	Fuel category and name	Storage Site	No. of units[c]	Mass (kilograms)[d]	Volume (cubic meters)[e]	Fissile mass (kilograms)	Equivalent uranium mass (kilograms)	MTHM
1.	Uranium metal[f]	INEEL	85	4,500	0.7	13	1,700	1.7
		Hanford	100,000	2,160,000	200	25,000	2,100,000	2100
		SRS	350	120,000	18	110	17,000	17
		Totals	*100,435*	*2,284,500*	*218.7*	*25,123*	*2,118,700*	*2119*
2.	Uranium-zirconium	INEEL	69	120	0.7	34	40	0.04
3.	Uranium-molybdenum	INEEL	29,000	4,600	0.3	970	3,800	3.8
4.	Uranium oxide, intact	INEEL	14,000	150,000	41	2,200	80,000	80
		Hanford	87	44,000	11	240	18,000	18
		Totals	*14,087*	*194,000*	*52*	*2,440*	*98,000*	*99*
5.	Uranium oxide, failed/declad/aluminum clad	INEEL	2,000	340,000	140	2,200	83,000	84
		Hanford	13	270	4.2	4	160	0.2
		SRS	7,600	58,000	96	2,600	3,200	3.2
		Totals	*9,613*	*398,270*	*240.2*	*4,804*	*86,360*	*87*
6.	Uranium-aluminide	SRS	18,000	130,000	150	6,000	8,800	8.7
7.	Uranium-silicide	SRS	7,400	47,000	53	1,200	12,000	12
8.	Thorium/uranium carbide, high-integrity	FSV	1,500	190,000	130	640	820	15
		INEEL	1,600	130,000	82	350	440	9.9
		Totals	*3,100*	*320,000*	*212*	*990*	*1,260*	*25*
9.	Thorium/uranium carbide, low-integrity	INEEL	810	55,000	17	180	210	1.7
10.	Plutonium/uranium carbide, nongraphite	INEEL	130	140	0	10	73	0.08
		Hanford	2	330	0.1	11	64	0.07
		Totals	*132*	*470*	*0.1*	*21*	*137*	*0.2*
11.	Mixed oxide	INEEL	2,000	6,100	2.4	240	2,000	2.1
		Hanford	620	110,000	33	2,400	8,000	10
		Totals	*2,620*	*116,100*	*35.1*	*2,640*	*10,000*	*12*
12.	Uranium/thorium oxide	INEEL	260	120,000	18	810	810	50
13.	Uranium-zirconium hydride	INEEL	9,800	33,000	8.1	460	2,000	2
		Hanford	190	660	33	7	36	0.04
		Totals	*9,990*	*33,660*	*8.3*	*467*	*2,036*	*2*
15.	Naval fuel[g]	INEEL	300	4,400,000	888	64,000	65,000	65
16.	Miscellaneous	INEEL	1,500	33,000	11	360	5,500	7.7
		Hanford	73	1,700	0.2	30	130	0.2
		SRS	8,800	9,200	8.2	550	2,900	2.9
		Totals	*10,373*	*43,900*	*19.4*	*940*	*8,530*	*11*
Grand totals			***210,000***	***8,150,000***	***1,900***	***110,000***	***2,420,000***	***2,500***

a. Source: DIRS 148240-Dirkmaat (1998, all).
b. Abbreviations: SNF = spent nuclear fuel; INEEL = Idaho National Engineering and Environmental Laboratory; SRS = Savannah River Site; FSV = Fort St. Vrain.
c. Unit is defined as an assembly, bundle of elements, can of material, etc., depending on the particular spent nuclear fuel category.
d. To convert kilograms to pounds, multiply by 2.2046; to convert metric tons to tons, multiply by 1.1023.
e. To convert cubic meters to cubic yards, multiply by 1.3079.
f. N-Reactor fuel is stored in aluminum or stainless-steel cans at the K-East and K-West Basins. The mass listed in this table does not include the storage cans.
g. Information supplied by the Navy (DIRS 104356-Dirkmaat 1997, Attachment, p. 2).

all the materials listed in the table as spent nuclear fuel, in accordance with the definition in the Nuclear Waste Policy Act, as amended.

A.2.2.4 Final Spent Nuclear Fuel Form

For all spent nuclear fuel categories except 14, the expected final spent nuclear fuel form does not differ from the current or planned storage form. Before its disposal in the repository, candidate material would be in compliance with approved acceptance criteria.

DOE has prepared an EIS at the Savannah River Site (DIRS 156897-DOE 2000, all) to evaluate potential treatment alternatives for spent nuclear fuel and its ultimate disposal in the repository. The products of any proposed treatment of the Savannah River Site aluminum-based fuels are adequately represented by the properties of the present aluminum-based fuel (Categories 6, 7, and part of 5) for this Yucca Mountain EIS. They are bounded by the same total radionuclide inventory, heat generation rates, dissolution rates, and number of canisters. No additional data about the products will be required to ensure that they are represented in the EIS inventory.

A.2.2.5 Spent Nuclear Fuel Characteristics

A.2.2.5.1 *Mass and Volume*

Table A-20 lists total volume, mass, and MTHM for each DOE spent nuclear fuel category from the National Spent Nuclear Fuel Database (DIRS 153072-Wheatley 2000, all).

A.2.2.5.2 *Amount and Nature of Radioactivity*

ORIGEN2 (Oak Ridge Isotope Generation), an accepted computer code for calculating spent nuclear fuel radionuclide inventories, was used to generate activity data for radionuclides in the DOE spent nuclear fuel inventory. The inventory came from the 1997 version of the National Spent Nuclear Fuel Database (DIRS 153072-Wheatley 2000, all).

Table A-21 lists the activities expressed in terms of curies per handling unit for the radionuclides of interest (uranium, fission products and actinides). The table lists activity estimates decayed to 2030 for all categories except 15. A handling unit for DOE is a spent nuclear fuel canister. The canister quantities (except the naval fuel) are estimated based on the fuel's current as-stored condition at each of the DOE facilities. The planned storage, transportation, and disposal unit for naval spent nuclear fuel is a canister. Each naval spent nuclear fuel canister would contain several spent fuel assemblies. The actual canister quantities for repository disposition could be different depending on final package configuration and whether the fuels were treated as discussed in Section A.1.1.3.

The activity for naval spent nuclear fuel (Category 15) is provided for a representative naval canister. DIRS 104356-Dirkmaat (1997, Attachment A, Table 3) provided these activities for 5 years after shutdown, which would be the minimum cooling time before naval fuel would reach the repository. The power history assumed operations at power for a full core life. The assumptions about the power history and minimum cooling time conservatively bound the activity for naval fuel that would be emplaced in a monitored geologic repository. In addition, ORIGEN-S was used to calculate the activity associated with activation products in the cladding, which are listed in Table A-21. For completeness, the data also include the activity that would be present in the activated corrosion products deposited on the fuel.

A.2.2.5.3 *Chemical Composition*

This section discusses the chemical compositions of each of the 16 categories of DOE spent nuclear fuel (DIRS 148240-Dirkmaat 1998, all).

- *Category 1: Uranium metal.* The fuel in this category consists primarily of uranium metal. N-reactor fuel represents the category because its mass is so large that the performance of the rest of the fuel in the category, even if greatly different from N-Reactor fuel, would not change the overall category performance. The fuel is composed of uranium metal about 1.25 percent enriched in uranium-235, and is clad with a zirconium alloy. Approximately 50 percent of the fuel elements are believed to have failed cladding. This fuel typically has low burnup. Another contributor to this category is the Single Pass Reactor fuel at the Hanford Site.

Table A-21. Radionuclide activity by DOE spent nuclear fuel category[a] (page 1 of 2).

	Category[c]														
Storage site[b]	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16
	Number of handling units														
Hanford	440	0	0	34	1	0	0	0	0	2	324	0	3	0	5
INEEL	6	8	70	195	406	0	0	503[d]	60	3	43	71	97	300	39
SRS	9	0	0	0	425	750	225	0	0	0	0	0	0	0	2
Totals	***455***	***8***	***70***	***229***	***832***	***750***	***225***	***503***	***60***	***5***	***367***	***71***	***100***	***300***	***46***
Radio-nuclide[g]	Curies per handling unit														
Ac-227	2.2×10^{-5}	4.8×10^{-9}	6.9×10^{-6}	1.7×10^{-4}	1.4×10^{-5}	3.4×10^{-7}	2.3×10^{-7}	0	2.8×10^{-3}	8.9×10^{-9}	1.5×10^{-9}	4.3×10^{-1}	5.6×10^{-8}	9.8×10^{-5}	6.8×10^{-7}
Am-241	1.1×10^{3}	3.9×10^{-1}	4.6×10^{-5}	1.6×10^{3}	7.3	3.3	3.6×10^{1}	3.7	2.7	2.4×10^{2}	4.3×10^{2}	8.3×10^{-1}	2.0×10^{-1}	5.0×10^{1}	1.2×10^{2}
Am-242m	6.6×10^{-2}	1.2×10^{-3}	0	2.6	1.4×10^{-2}	2.3×10^{-3}	1.3×10^{-2}	1.0×10^{-3}	1.4×10^{-3}	4.1×10^{-1}	7.5×10^{-1}	8.7×10^{-3}	2.3×10^{-3}	4.6×10^{-1}	1.5×10^{-1}
Am-243	2.8×10^{-1}	3.8×10^{-3}	7.3×10^{-13}	8.3	2.2×10^{-2}	2.5×10^{-3}	3.6×10^{-2}	2.7×10^{-2}	1.3×10^{-3}	6.7×10^{-3}	1.8×10^{-1}	1.7×10^{-3}	2.5×10^{-4}	6.7×10^{-1}	4.9×10^{-1}
C-14	1.5	8.2×10^{-6}	2.2×10^{-3}	1.0×10^{-1}	1.1×10^{-3}	9.9×10^{-7}	1.8×10^{-5}	2.2×10^{-1}	3.7×10^{-2}	1.5×10^{-5}	9.9×10^{-4}	6.7×10^{-1}	8.5×10^{-2}	1.6×10^{1}	1.7×10^{-3}
Cf-252	--[e]	--	--	--	--	--	--	--	--	--	--	--	--	1.2×10^{-6}	--
Cl-36	0	0	5.6×10^{-6}	3.5×10^{-4}	1.7×10^{-5}	0	0	2.7×10^{-3}	1.1×10^{-3}	0	1.1×10^{-5}	1.5×10^{-2}	2.6×10^{-3}	6.9×10^{-1}	4.2×10^{-6}
Cm-242	$< 7.4\times10^{1}$	$< 7.4\times10^{1}$	0	$< 7.4\times10^{1}$	$< 7.4\times10^{1}$	$< 7.4\times10^{1}$	$< 7.4\times10^{1}$	$< 7.4\times10^{1}$	$< 7.4\times10^{1}$	$< 7.4\times10^{1}$	$< 7.4\times10^{1}$	$< 7.3\times10^{1}$	$< 7.4\times10^{1}$	1.4	$< 7.4\times10^{1}$
Cm-243	--	--	--	--	--	--	--	--	--	--	--	--	--	7.9×10^{-1}	
Cm-244	8.5	1.6×10^{-1}	6.8×10^{-14}	3.5×10^{2}	9.3×10^{-1}	2.1×10^{-2}	3.0×10^{-1}	8.3×10^{-1}	3.5×10^{-2}	2.8×10^{-1}	7.6	1.6×10^{-1}	6.8×10^{-3}	6.3×10^{1}	1.9×10^{1}
Cm-245	3.6×10^{-3}	8.0×10^{-6}	1.9×10^{-19}	1.4×10^{-1}	3.8×10^{-4}	1.8×10^{-6}	2.0×10^{-5}	1.4×10^{-4}	4.0×10^{-6}	1.4×10^{-5}	3.1×10^{-3}	3.3×10^{-5}	1.4×10^{-7}	7.2×10^{-3}	7.1×10^{-3}
Cm-246	5.3×10^{-4}	5.5×10^{-7}	6.1×10^{-23}	2.4×10^{-2}	6.4×10^{-5}	8.6×10^{-8}	1.5×10^{-6}	6.9×10^{-5}	1.3×10^{-7}	9.7×10^{-7}	5.3×10^{-4}	2.2×10^{-6}	3.9×10^{-9}	1.4×10^{-3}	1.2×10^{-3}
Cm-247	--	--	--	--	--	--	--	--	--	--	--	--	--	9.4×10^{-9}	--
Cm-248	--	--	--	--	--	--	--	--	--	--	--	--	--	2.6×10^{-8}	--
Co-60	1.4×10^{-1}	0	1.1×10^{-2}	1.8×10^{1}	1.6×10^{-12}	1.2×10^{-11}	2.0×10^{-10}	0	2.5×10^{-2}	1.8	1.4	4.3	1.8×10^{-1}	3.7×10^{3}[f]	7.6×10^{-4}
Cs-134	2.7×10^{-1}	4.6×10^{-2}	1.9×10^{-8}	9.6×10^{-2}	8.3×10^{-3}	1.7×10^{-1}	3.7×10^{-1}	7.6×10^{-3}	3.6×10^{-7}	3.4×10^{-2}	7.5×10^{-3}	6.0×10^{-3}	3.3×10^{-4}	8.4×10^{4}	5.7×10^{-1}
Cs-135	1.8×10^{-1}	7.7×10^{-3}	4.5×10^{-3}	1.8×10^{-1}	2.9×10^{-2}	2.8×10^{-2}	1.9×10^{-2}	1.7×10^{-2}	2.6×10^{-2}	1.4×10^{-2}	3.2×10^{-3}	2.0×10^{-1}	3.2×10^{-2}	4.6	1.4×10^{-1}
Cs-137	2.0×10^{4}	7.4×10^{3}	0	2.9×10^{4}	3.6×10^{3}	3.8×10^{3}	8.1×10^{3}	2.4×10^{3}	1.9×10^{3}	1.5×10^{4}	4.0×10^{3}	2.5×10^{3}	3.1×10^{3}	4.5×10^{5}	8.7×10^{4}
H-3	2.3×10^{1}	4.4	8.6×10^{-2}	3.6×10^{1}	1.3	5.9×10^{-1}	1.3×10^{1}	2.0	1.5	7.3	2.8	2.3×10^{1}	9.6×10^{-1}	1.4×10^{3}	1.3×10^{1}
I-129	1.6×10^{-2}	1.6×10^{-3}	1.2×10^{-4}	1.8×10^{-2}	7.5×10^{-4}	1.8×10^{-3}	3.8×10^{-3}	2.1×10^{-3}	7.3×10^{-4}	2.9×10^{-3}	3.6×10^{-4}	1.1×10^{-2}	7.2×10^{-4}	1.2×10^{-1}	2.3×10^{-2}
Kr-85	3.6×10^{2}	9.3×10^{1}	7.7×10^{-1}	3.1×10^{2}	2.7×10^{1}	1.3×10^{2}	2.6×10^{2}	6.0×10^{1}	7.2	4.8×10^{1}	2.4×10^{1}	6.2×10^{2}	1.7×10^{1}	3.6×10^{4}	4.2×10^{2}
Nb-93m	8.0×10^{-1}	8.7×10^{-3}	4.6×10^{-3}	6.7×10^{-1}	1.1×10^{-2}	1.6×10^{-2}	3.1×10^{-2}	9.2×10^{-3}	4.6×10^{-2}	1.5×10^{-2}	1.3×10^{-2}	3.1×10^{-1}	7.1×10^{-3}	3.6	1.7×10^{-1}
Nb-94	5.7×10^{-6}	1.6×10^{-6}	8.4×10^{-4}	7.3×10^{-3}	4.2×10^{-5}	3.1×10^{-6}	7.4×10^{-6}	1.3×10^{-4}	4.9×10^{-4}	2.9×10^{-6}	1.9×10^{-5}	1.6×10^{-2}	4.6×10^{-3}	1.8×10^{2}	3.5×10^{-5}
Ni-59	8.2×10^{-2}	0	6.9×10^{-3}	9.4×10^{-2}	2.3×10^{-4}	0	0	1.7×10^{-2}	1.5×10^{-3}	0	2.1×10^{-3}	5.1×10^{-2}	5.0×10^{-1}	6.3×10^{1}	8.2×10^{-4}
Ni-63	7.7	0	1.4×10^{-1}	3.0×10^{2}	2.5×10^{-2}	2.3×10^{-22}	0	4.1×10^{-1}	1.5×10^{-1}	5.0	8.7	6.2	6.2×10^{1}	7.8×10^{3}	1.0×10^{-1}
Np-237	1.7×10^{-1}	2.0×10^{-2}	3.3×10^{-4}	1.8×10^{-1}	3.1×10^{-3}	1.2×10^{-2}	1.8×10^{-2}	1.6×10^{-2}	7.4×10^{-3}	3.7×10^{-2}	6.5×10^{-3}	7.1×10^{-4}	1.9×10^{-3}	1.6	2.4×10^{-1}
Pa-231	5.8×10^{-5}	2.3×10^{-7}	2.0×10^{-5}	3.0×10^{-4}	2.6×10^{-5}	4.2×10^{-6}	2.8×10^{-6}	1.9×10^{-2}	4.8×10^{-3}	4.1×10^{-7}	1.2×10^{-7}	1.1	9.0×10^{-7}	5.2×10^{-4}	1.0×10^{-5}
Pb-210	3.2×10^{-10}	8.6×10^{-13}	1.4×10^{-10}	9.0×10^{-8}	5.2×10^{-9}	2.1×10^{-11}	1.2×10^{-11}	4.6×10^{-6}	2.6×10^{-7}	1.5×10^{-12}	3.1×10^{-10}	7.8×10^{-5}	1.4×10^{-12}	8.9×10^{-7}	7.510^{-10}

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Table A-21. Radionuclide activity by DOE spent nuclear fuel category[a] (page 2 of 2).

Radio-nuclide[g]	Category[b]														
	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16
	Curies per handling unit														
Pd-107	3.3×10^{-2}	1.1×10^{-3}	1.3×10^{-4}	4.8×10^{-2}	8.3×10^{-4}	9.3×10^{-4}	3.5×10^{-3}	8.7×10^{-4}	4.8×10^{-4}	2.0×10^{-3}	1.0×10^{-3}	2.4×10^{-3}	6.0×10^{-4}	6.0×10^{-2}	1.8×10^{-2}
Pu-238	2.5×10^{2}	4.3×10^{1}	1.7×10^{-2}	1.2×10^{3}	5.8	1.7×10^{1}	2.8×10^{1}	8.1×10^{1}	1.8×10^{1}	1.1×10^{2}	7.9×10^{1}	2.8	2.1	1.2×10^{4}	5.3×10^{2}
Pu-239	5.1×10^{2}	1.1	2.0	1.5×10^{2}	1.3×10^{1}	2.4	2.2×10^{1}	2.3×10^{-1}	4.1×10^{-1}	1.9×10^{2}	3.2×10^{2}	1.8×10^{-1}	4.5	1.2×10^{1}	5.2×10^{1}
Pu-240	3.0×10^{2}	6.1×10^{-1}	6.1×10^{-3}	2.4×10^{2}	4.4	1.2	1.6×10^{1}	3.8×10^{-1}	3.2×10^{-1}	1.6×10^{2}	2.8×10^{2}	1.0x10-1	1.8	1.4×10^{1}	3.7×10^{1}
Pu-241	3.8×10^{3}	2.1×10^{2}	6.0×10^{-4}	1.4×10^{4}	2.9×10^{2}	6.3×10^{1}	7.0×10^{2}	0	3.0×10^{1}	1.7×10^{3}	2.6×10^{3}	2.4×10^{1}	1.3×10^{2}	4.0×10^{3}	3.5×10^{3}
Pu-242	1.6×10^{-1}	9.2×10^{-4}	3.8×10^{-11}	9.1×10^{-1}	3.0×10^{-3}	9.9×10^{-4}	1.6×10^{-2}	0	4.2×10^{-4}	1.6×10^{-3}	2.0×10^{-2}	2.3×10^{-4}	2.5×10^{-4}	8.0×10^{-2}	7.0×10^{-2}
Ra-226	4.6×10^{-6}	2.2×10^{-12}	6.5×10^{-10}	2.6×10^{-7}	2.0×10^{-8}	3.8×10^{-10}	2.3×10^{-10}	4.9×10^{-6}	9.3×10^{-7}	2.3×10^{-9}	5.3×10^{-9}	4.5×10^{-5}	2.3×10^{-12}	5.4×10^{-6}	4.1×10^{-9}
Ra-228	3.7×10^{-10}	1.2×10^{-13}	4.0×10^{-9}	1.3×10^{-4}	1.1×10^{-5}	7.3×10^{-13}	1.1×10^{-12}	6.5×10^{-3}	2.4×10^{-3}	6.9×10^{-13}	2.0×10^{-11}	7.1×10^{-2}	3.5×10^{-9}	1.8×10^{-7}	1.5×10^{-11}
Rh-102	--	--	--	--	--	--	--	--	--	--	--	--	--	2.8×10^{-2}	--
Ru-106	3.1×10^{-5}	6.3×10^{-7}	3.1×10^{-15}	3.9×10^{-7}	1.2×10^{-6}	1.3×10^{-5}	4.2×10^{-5}	3.2×10^{-9}	3.0×10^{-15}	2.6×10^{-6}	3.1×10^{-8}	2.2×10^{-10}	1.5×10^{-9}	6.0×10^{3}	5.7×10^{-5}
Se-79	2.6×10^{-1}	3.0×10^{-2}	1.7×10^{-3}	1.9×10^{-1}	1.6×10^{-2}	5.0×10^{-2}	1.0×10^{-1}	2.9×10^{-2}	1.4×10^{-2}	5.2×10^{-2}	3.6×10^{-3}	2.5×10^{-1}	1.3×10^{-2}	3.4×10^{-1}	4.7×10^{-1}
Sm-151	3.3×10^{2}	2.7×10^{1}	6.9	5.3×10^{2}	2.5×10^{1}	4.2×10^{1}	3.4×10^{1}	4.5×10^{1}	2.6×10^{1}	1.8×10^{2}	2.4×10^{2}	9.1×10^{1}	2.4×10^{1}	1.4×10^{3}	3.8×10^{2}
Sn-126	3.5×10^{-1}	2.6×10^{-2}	3.8×10^{-3}	2.4×10^{-1}	1.2×10^{-2}	1.7×10^{-2}	4.1×10^{-2}	1.4×10^{-2}	1.2×10^{-2}	4.7×10^{-2}	4.8×10^{-3}	2.8×10^{-1}	1.2×10^{-2}	1.2	3.3×10^{-1}
Sr-90	1.6×10^{4}	7.1×10^{3}	0	2.1×10^{4}	3.2×10^{3}	3.7×10^{3}	7.6×10^{3}	2.3×10^{3}	1.8×10^{3}	1.3×10^{4}	1.6×10^{3}	2.6×10^{3}	2.9×10^{3}	4.4×10^{5}	8.3×10^{4}
Tc-99	7.7	9.9×10^{-1}	4.5×10^{-2}	6.6	4.2×10^{-1}	1.0	2.2	7.4×10^{-1}	4.1×10^{-1}	1.8	1.3×10^{-1}	2.3	4.3×10^{-1}	7.0×10^{1}	1.4×10^{1}
Th-229	3.9×10^{-8}	1.1×10^{-10}	2.4×10^{-9}	4.0×10^{-4}	3.2×10^{-5}	2.2×10^{-9}	1.2×10^{-9}	2.8×10^{-2}	6.8×10^{-3}	2.5×10^{-10}	1.7×10^{-9}	1.8×10^{-1}	1.2×10^{-9}	9.4×10^{-6}	8.7×10^{-9}
Th-230	4.4×10^{-6}	8.6×10^{-9}	1.2×10^{-7}	3.7×10^{-5}	2.9×10^{-6}	1.8×10^{-7}	1.2×10^{-7}	1.9×10^{-3}	1.3×10^{-4}	5.1×10^{-7}	1.2×10^{-6}	6.9×10^{-3}	3.9×10^{-9}	1.8×10^{-3}	1.2×10^{-6}
Th-232	5.1×10^{-10}	2.0×10^{-12}	4.3×10^{-9}	1.4×10^{-4}	1.2×10^{-5}	1.9×10^{-11}	3.0×10^{-11}	5.1×10^{-3}	2.5×10^{-3}	4.4×10^{-12}	5.5×10^{-11}	8.4×10^{-2}	1.0×10^{-8}	2.3×10^{-7}	9.8×10^{-11}
U-232	9.9×10^{-5}	3.5×10^{-5}	1.9×10^{-6}	0	2.2×10^{-5}	1.7×10^{-4}	1.4×10^{-4}	2.3	2.4×10^{-1}	0	0	7.1×10^{2}	2.4×10^{-5}	5.6×10^{-1}	3.5×10^{-4}
U-233	2.5×10^{-5}	9.1×10^{-7}	9.9×10^{-7}	1.6×10^{-1}	1.2×10^{-2}	2.6×10^{-6}	1.8×10^{-6}	6.9	2.6	1.7×10^{-6}	9.3×10^{-7}	1.2×10^{2}	5.6×10^{-6}	3.1×10^{-3}	1.6×10^{-5}
U-234	2.0	8.6×10^{-4}	5.0×10^{-4}	1.7×10^{-1}	1.1×10^{-2}	2.2×10^{-3}	1.8×10^{-3}	5.6×10^{-1}	4.4×10^{-1}	4.9×10^{-3}	8.0×10^{-3}	5.9	2.1×10^{-4}	1.5×10^{1}	1.8×10^{-2}
U-235	8.4×10^{-2}	8.2×10^{-3}	3.2×10^{-2}	1.7×10^{-2}	1.2×10^{-2}	1.8×10^{-2}	1.3×10^{-2}	2.2×10^{-3}	6.8×10^{-3}	1.5×10^{-2}	2.2×10^{-4}	4.0×10^{-4}	9.9×10^{-3}	2.9×10^{-1}	1.2×10^{-1}
U-236	3.3×10^{-1}	3.4×10^{-2}	1.7	1.4×10^{-1}	1.2×10^{-2}	3.7×10^{-2}	5.9×10^{-2}	2.1×10^{-2}	1.7×10^{-2}	6.0×10^{-2}	4.1×10^{-3}	8.1×10^{-4}	1.3×10^{-2}	2.5	4.4×10^{-1}
U-238	1.6	1.5×10^{-4}	1.4×10^{-2}	1.3×10^{-1}	3.4×10^{-2}	8.9×10^{-4}	1.6×10^{-2}	5.4×10^{-5}	7.1×10^{-5}	2.7×10^{-4}	2.7×10^{-3}	1.3×10^{-5}	5.8×10^{-3}	1.2×10^{-3}	2.4×10^{-2}
Zr-93	1.0	1.5×10^{-1}	6.7×10^{-3}	9.1×10^{-1}	5.0×10^{-2}	1.0×10^{-1}	2.1×10^{-1}	1.1	6.4×10^{-2}	2.7×10^{-1}	1.7×10^{-2}	5.7×10^{-1}	7.8×10^{-2}	1.1×10^{1}	1.9

a. Source: DIRS 148240-Dirkmaat (1998, all); DIRS 155857-McKenzie (2001, Attachment B, p. 9). Values are rounded to two significant figures.
b. INEEL = Idaho National Engineering and Environmental Laboratory; SRS = Savannah River Site.
c. Categories 1-13 and 16 decayed to 2030. Category 15 cooled for 5 years.
d. Includes 334 canisters from Fort St. Vrain.
e. -- = not found in appreciable quantities.
f. Amount of cobalt-60 as crud is 5.8 curies.
g. Half-lives are listed in Table A-11, with the exception of Cf-252 = 2.65 years, Cm-242 = 1.6×10^{7} years, Cm-248 = 3.4×10^{5} years, Rh-102 = 2.9 years, Th-229 = 7.9×10^{3} years, and Th-232 = 1.4×10^{10} years.

- *Category 2: Uranium-zirconium.* The fuel in this category consists primarily of a uranium- (91 percent) zirconium alloy. The Heavy Water Components Test Reactor fuel is the representative fuel because it is the largest part of the inventory. This fuel is approximately 85-percent enriched in uranium-235 and is clad with a zirconium alloy.

- *Category 3: Uranium molybdenum.* The fuel in this category consists of uranium- (10 percent)- molybdenum alloy and 25-percent enriched in uranium-235, and is clad with a zirconium alloy. Fermi driver core 1 and 2 are the only fuels in the category. The fuel is currently in an aluminum container. The proposed disposition would include the aluminum container.

- *Category 4: Uranium oxide, intact.* The fuel in this category consists of uranium oxide that has been formed into pellets or plates and clad with a corrosion-resistant material. Commercial fuel is the representative fuel for this category because it is a large part of the inventory. The fuel is made of uranium oxide, some of which is highly enriched in uranium-235 and some of which is low enriched in uranium-235. The fuel elements are clad with a zirconium alloy.

- *Category 5: Uranium oxide, failed/declad/aluminum clad.* The fuel in this category is chemically similar to the fuels in Category 4, except accident or destructive examination has disrupted it. The failed fuel from Three Mile Island Reactor 2 represents this category because it comprises 96 percent of the total MTHM of the category. The Three Mile Island Reactor 2 fuel is melted uranium oxide. The accident greatly disrupted the cladding. Other fuel in this category is declad or has a large amount of cladding damage. Approximately 4 percent consists of intact aluminum clad fuel included in this category because the aluminum cladding is less corrosion resistant than Category 4 cladding material.

- *Category 6: Uranium-aluminide.* This category consists of fuel with a uranium-aluminum compound dispersed in a continuous aluminum metal phase. The fuel is clad with an aluminum alloy. The uranium-235 enrichment varies from 10 to 93 percent.

- *Category 7: Uranium-silicide.* The fuel in this category is a uranium-silicide compound dispersed in a continuous aluminum metal phase. The fuel is clad with an aluminum alloy. The uranium-235 enrichment varies from 8 to 93 percent, but most are less than 20 percent.

- *Category 8: Thorium/uranium carbide, high-integrity.* This category consists of fuels with thorium carbide or uranium carbide formed into particles with a high-integrity coating. Fort St. Vrain Reactor fuel represents the category because it makes up 95 percent of the mass of the category. This fuel is uranium carbide and thorium carbide formed into particles and coated with layers of pyrolytic carbon and silicon carbide. The particles are bonded in a carbonaceous matrix material and emplaced in a graphite block. The fuel was made with uranium enriched to 93 percent in uranium-235. The thorium was used to generate fissile uranium-233 during irradiation. Some fuel does not have a silicon carbide coating, but its effect on the category is very small. Less than 1 percent of the fuel particles are breached.

- *Category 9: Thorium/uranium carbide, low-integrity.* This category consists of fuels with uranium carbide or thorium carbide made into particles with a coating of an earlier design than that described for Category 8. Peach Bottom Unit 1, Core 1 is the only fuel in this category. This fuel is chemically similar to Category 8 fuel except 60 percent of the particle coating is breached. Peach Bottom Unit 1, Core 2 is included in Category 8 because its fuel particles are basically intact and are more rugged than the Peach Bottom Unit 1, Core 1 particles.

- *Category 10: Plutonium/uranium carbide, nongraphite.* This category consists of fuel that contains uranium carbide. Much of it also contains plutonium carbide. Fast Flux Test Facility carbide assemblies represent this category because they make up 70 percent of the category and contain both uranium and plutonium. The Fast Flux Test Facility carbide fuel was constructed from uncoated uranium and plutonium carbide spheres that were loaded directly into the fuel pins, or pressed into pellets that were loaded into the pins. The pins are clad with stainless steel.

- *Category 11: Mixed oxide.* This category consists of fuels constructed of both uranium oxide and plutonium oxide. The Fast Flux Test Facility mixed-oxide test assembly is the representative fuel because it comprises more than 80 percent of the category. The fuels are a combination of uranium oxide and plutonium oxide pressed into pellets and clad with stainless steel or a zirconium alloy. The uranium-235 enrichment is low, but the fissile contribution of the plutonium raises the effective enrichment to 15 percent.

- *Category 12: Uranium/thorium oxide.* This category consists of fuels constructed of uranium oxide and thorium oxide. Shippingport light-water breeder reactor fuel is the representative fuel because it comprises more than 75 percent of the inventory. The Shippingport light-water breeder reactor fuel is made of uranium-233, and the irradiation of the thorium produces more uranium-233. The mixture is pressed into pellets and clad with a zirconium alloy.

- *Category 13: Uranium-zirconium hydride.* This category consists of fuels made of uranium-zirconium hydride. Training Research Isotopes-General Atomic fuels comprise more than 90 percent of the mass of this category. The fuel is made of uranium-zirconium hydride formed into rods and clad primarily with stainless steel or aluminum. The uranium is enriched as high as 90 percent in uranium-235, but most is less than 20 percent enriched.

- *Category 14: Sodium-bonded.* For purposes of analysis in this EIS, it is assumed that all Category 14 fuels would be treated during the proposed electrometallurgical treatment that would result in high-level radioactive waste. The chemical composition of the resulting high-level radioactive waste is described in Section A.2.3.5.3. Category 14 is included here for completeness.

- *Category 15: Naval fuel.* Naval nuclear fuel is highly robust and designed to operate in a high-temperature, high-pressure environment for many years. This fuel is highly enriched (93 to 97 percent) in uranium-235. In addition, to ensure that the design will be capable of withstanding battle shock loads, the naval fuel material is surrounded by large amounts of zirconium alloy (DIRS 124679-Beckett 1998, Attachment 2).

  DOE plans to emplace approximately 300 canisters of naval spent nuclear fuel in the Yucca Mountain Repository. There are several different designs for naval nuclear fuel, but all designs employ similar materials and mechanical arrangements. The total weight of typical fuel assemblies in a canister would be 11,000 to 13,000 kilograms (24,000 to 29,000 pounds). Of this total, less than 500 kilograms (1,100 pounds) would be uranium. Approximately 1,000 to 2,000 kilograms (2,200 to 4,400 pounds) of the total weight of these fuel assemblies is from hafnium in the poison devices (primarily control rods) permanently affixed to the fuel assemblies (DIRS 124679-Beckett 1998, Attachment 2).

  There would be approximately 9,000 to 12,000 kilograms (20,000 to 26,500 pounds) of zirconium alloy in the fuel structure in the typical canister. The typical chemical composition of zirconium alloy is approximately 98 percent zirconium, 1.5 percent tin, 0.2 percent iron, and 0.1 percent chromium (DIRS 124679-Beckett 1998, Attachment 2).

The small remainder of the fuel mass in a typical canister of naval spent nuclear fuel [less than 500 kilograms (1,100 pounds)] would consist of small amounts of such metals and nonmetals as fission products and oxides (DIRS 124679-Beckett 1998, Attachment 2).

- *Category 16: Miscellaneous.* This category consists of the fuels that do not fit into the previous 15 categories. The largest amount of this fuel, as measured in MTHM, is uranium metal or alloy. The other two primary contributors are uranium alloy and uranium-thorium alloy. These three fuel types make up more than 80 percent of the MTHM in the category. It is conservative to treat the total category as uranium metal. Other chemical compounds included in this category include uranium oxide, uranium nitride, uranium alloys, plutonium oxide, plutonium nitride, plutonium alloys, and thorium oxide.

Table A-22 lists the primary materials of construction and chemical composition for each category.

A.2.2.5.4 *Thermal Output*

Table A-23 lists the maximum heat generation per handling unit for each spent nuclear fuel category (DIRS 104354-Dirkmaat 1997, Attachment, pp. 74 to 77; DIRS 104377-Dirkmaat 1998, all). The category 15 (naval fuel) thermal data used the best estimate radionuclide content from DIRS 104354-Dirkmaat (1997, Attachment, pp. 74 to 77) at a minimum cooling time of 5 years.

A.2.2.5.5 *Quantity of Spent Nuclear Fuel Per Canister*

Table A-24 lists the projected number of canisters required for each site and category. The amount of fuel per canister would vary widely among categories and would depend on a variety of parameters. The average mass of naval spent nuclear fuel in a short naval canister would be approximately 13 metric tons (14 tons) with an associated volume of 2.7 cubic meters (95 cubic feet). Naval spent nuclear fuel in a long naval canister would have an average mass of approximately 18 metric tons (20 tons) and a volume of 3.5 cubic meters (124 cubic feet) (DIRS 104354-Dirkmaat 1997, Attachment, p. 108).

A.2.2.5.6 *Spent Nuclear Fuel Canister Parameters*

The Idaho National Engineering and Environmental Laboratory would use a combination of 46- and 61-centimeter (18- and 24-inch)-diameter stainless-steel canisters for spent nuclear fuel disposition. The Savannah River Site would use 18-inch canisters, and Hanford would use 64-centimeter (25.3-inch) multicanister overpacks and 18-inch canisters. Table A-24 lists the specific number of canisters per site. Detailed canister design specifications for the standard 18- and 24-inch canisters are contained in DIRS 137713-DOE (1998, all). Specifications for the Hanford multicanister overpacks are in DIRS 103499-Parsons (1999, all).

There are two conceptual canister designs for naval fuel: one with a length of 539 centimeters (212 inches) and one with a length of 475 centimeters (187 inches). Both canisters would have a maximum diameter of 169 centimeters (67 inches) (DIRS 104354-Dirkmaat 1997, Attachment, pp. 86 to 88). Table A-25 summarizes the preliminary design information.

For both designs, the shield plug, shear ring, and outer seal plate would be welded to the canister shell after the fuel baskets were loaded in the canister. The shield plug, shear ring, and welds, along with the canister shell and bottom plug, would form the containment boundary for the disposable container. The shell, inner cover, and outer cover material for the two canisters would be low-carbon austenitic stainless steel or stabilized austenitic stainless steel. Shield plug material for either canister would be stainless steel (DIRS 104354-Dirkmaat 1997, Attachment, pp. 86 to 88).

Table A-22. Chemical composition of DOE spent nuclear fuel by category (kilograms).[a,b]

Fuel	Category														
	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16
Components															
Uranium	2,120,000	40	3,800	98,000	87,000	8,800	12,000	1,300	210	140	9,900	810	2,000	65,000	8,500
Aluminum	1,700	(c)				18,000	4,200								
Molybdenum			380										9		
Zirconium	140	440		7,500									23,000		
Thorium								27,000	1,500			48,000			2,200
Plutonium										16	2,400				8
Silicon	260						880								
Silicon carbide								53,000							
Carbon	1,200			30				220,000	53,000				1,700		
Cladding and structure															
Aluminum	100		640		18,000	64,000	52,000						11,000		500
Stainless steel				11,000	3,000				8,000	320	2,400	31,000	17,000		20,000
Zirconium alloy	160,000	70	280	64,000	58,000						500	12,000	100	3,600,000	100
Inconel				1,000	1,700										
Container															
Stainless steel	2,640,000	5,600	50,000	165,000	750,000	900,000	270,000	500,000	42,000	3,500	260,000	50,000	70,000	9,900,000	31,000
Aluminum			660		10,000										
Other															
Concrete					30,000[d]										
Boron					500	1,000	300		29						
Silver					1,100										
Cadmium					34										
Indium					280										
Magnesium									430						
Nickel	210														
Rhodium									30						
Ruthenium									30						
Samarium													67		
Gadolinium					530	950	23								
Hafnium														600,000	

a. Source: DIRS 148240-Dirkmaat (1998, all); DIRS 104377-Dirkmaat (1998, p. 008/016, 009/016); values are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Blanks indicate none or less than reportable quantities.
d. Low density converters were added to canisters of Three Mile Island Unit 2 fuel and would remain when shipped to the repository.

Table A-23. Maximum heat generation for DOE spent nuclear fuel (watts per handling unit).[a,b]

	Category and fuel type	Maximum heat generation
1.	Uranium metal	18
2.	Uranium zirconium	90
3.	Uranium molybdenum	4
4.	Intact uranium oxide	1,000
5.	Failed/declad/aluminum clad uranium oxide	800
6.	Uranium aluminide	480
7.	Uranium silicide	1,400
8.	High-integrity thorium/uranium carbide	250
9.	Low-integrity thorium/uranium carbide	37
10.	Nongraphite plutonium/uranium carbide	1,800
11.	Mixed oxide	1,800
12.	Thorium/uranium oxide	600
13.	Uranium zirconium hydride	100
14.	Sodium-bonded	N/A[c]
15.	Naval fuel	4,250
16.	Miscellaneous	1,000

a. Sources: DIRS 104354-Dirkmaat (1997, Attachment, pp. 74 to 77); DIRS 104377-Dirkmaat (1998, Table A.2.2-3); DIRS 156933-Fillmore (2001, all).
b. Handling unit is a canister.
c. N/A = not applicable. Assumed to be treated and therefore part of high-level radioactive waste inventory (see Section A.2.2.1).

Table A-24. Required number of canisters for disposal of DOE spent nuclear fuel.[a,b]

	Hanford		INEEL		SRS	Naval	
Category	18-inch	25.3-inch	18-inch	24-inch	18-inch	Short	Long
1		440	6		9		
2			8				
3			70				
4	14	20	179	16			
5	1		406		425		
6					750		
7					225		
8			503[c]				
9			60				
10	2		3				
11	324		43				
12			24	47			
13	3		97				
14[d]							
15						200	100
16	5		39		2		
Totals	***349***	***460***	***1,438***	***63***	***1,411***	***200***	***100***

a. Sources: DIRS 104356-Dirkmaat (1997, Attachment, p. 2); Dirkmaat (DIRS 148240-1998, all).
b. INEEL = Idaho National Engineering and Environmental Laboratory; SRS = Savannah River Site.
c. Includes 334 canisters from Fort St. Vrain.
d. Assumed to be treated and therefore part of high-level radioactive waste inventory (see Section A.2.2.1).

Table A-25. Preliminary naval canister design parameters.[a]

Parameter	Short canister	Long canister
Maximum outside diameter (centimeters)[b,c]	169	169
Maximum outer length (centimeters)	475	539
Minimum loaded weight (metric tons)[d]	27	27
Maximum loaded weight (metric tons)	45	45

a. Source: DIRS 104354-Dirkmaat (1997, Attachment, pp. 86 to 88).
b. To convert centimeters to inches, multiply by 0.3937.
c. Right circular cylinder.
d. To convert metric tons to tons, multiply by 1.1023.

A.2.3 HIGH-LEVEL RADIOACTIVE WASTE

High-level radioactive waste is the highly radioactive material resulting from the reprocessing of spent nuclear fuel. DOE stores high-level radioactive waste at the Hanford Site, the Savannah River Site, and the Idaho National Engineering and Environmental Laboratory. Between 1966 and 1972, commercial chemical reprocessing operations at the Nuclear Fuel Services plant near West Valley, New York, generated a small amount of high-level radioactive waste at a site presently owned by the New York State Energy Research and Development Authority. These operations ceased after 1972. In 1980, Congress passed the West Valley Demonstration Project Act, which authorizes DOE to conduct, with the Research and Development Authority, a demonstration of solidification of high-level radioactive waste for disposal and the decontamination and decommissioning of demonstration facilities (DIRS 102588-DOE 1992, Chapter 3). This section addresses defense high-level radioactive waste generated at the DOE sites (Hanford Site, Idaho National Engineering and Environmental Laboratory, and Savannah River Site) and commercial high-level radioactive waste generated at the West Valley Demonstration Project.

A.2.3.1 Background

In 1985, DOE published a report in response to Section 8 of the Nuclear Waste Policy Act (of 1982) that required the Secretary of Energy to recommend to the President whether defense high-level radioactive waste should be disposed of in a geologic repository along with commercial spent nuclear fuel. That report, *An Evaluation of Commercial Repository Capacity for the Disposal of Defense High-Level Waste* (DIRS 103492-DOE 1985, all), provided the basis, in part, for the President's determination that defense high-level radioactive waste should be disposed of in a geologic repository. Given that determination, DOE decided to allocate 10 percent of the capacity of the first repository for the disposal of DOE spent nuclear fuel (2,333 MTHM) and high-level radioactive waste (4,667 MTHM) (DIRS 104384-Dreyfuss 1995, all; DIRS 104398-Lytle 1995, all).

Calculating the MTHM quantity for spent nuclear fuel is straightforward. It is determined by the actual heavy metal content of the spent fuel. However, an equivalence method for determining the MTHM in defense high-level radioactive waste is necessary because almost all of its heavy metal has been removed. A number of alternative methods for determining MTHM equivalence for high-level radioactive waste have been considered over the years. Four of those methods are described in the following paragraphs.

Historical Method. Table 1-1 of DIRS 103492-DOE (1985) provided a method to estimate the MTHM equivalence for high-level radioactive waste based on comparing the radioactive (curie) equivalence of commercial high-level radioactive waste and defense high-level radioactive waste. The method relies on the relative curie content of a hypothetical (in the early 1980s) canister of defense high-level radioactive waste from the Savannah River, Hanford, or Idaho site, and a hypothetical canister of vitrified waste from reprocessing of high-burnup commercial spent nuclear fuel. Based on commercial high-level radioactive waste containing 2.3 MTHM per canister (heavy metal has not been removed from commercial waste) and defense high-level radioactive waste estimated to contain approximately 22 percent of the radioactivity of a canister of commercial high-level radioactive waste, defense high-level radioactive waste was estimated to contain the equivalent of 0.5 MTHM per canister. Since 1985, DOE has used this 0.5 MTHM equivalence per canister of defense high-level radioactive waste in its consideration of the potential impacts of the disposal of defense high-level radioactive waste, including the analysis presented in this EIS. With this method, less than 50 percent of the total inventory of high-level radioactive waste could be disposed of in the repository within the 4,667 MTHM allocation for high-level radioactive waste. There has been no determination of which waste would be shipped to the repository, or the order of shipments.

Spent Nuclear Fuel Reprocessed Method. Another method of determining MTHM equivalence, based on the quantity of spent nuclear fuel reprocessed, would be to consider the MTHM in the high-level radioactive waste to be the same as the MTHM in the spent nuclear fuel before it was reprocessed. Using this method, less than 5 percent of the total inventory of high-level radioactive waste could be disposed of in the repository within the 4,667 MTHM allocation for high-level radioactive waste.

Total Radioactivity Method. Another method, the total radioactivity method, would establish equivalence based on a comparison of radioactivity inventory (curies) of defense high-level radioactive waste to that of a standard MTHM of commercial spent nuclear fuel. For this equivalence method the standard spent nuclear fuel characteristics are based on pressurized-water reactor fuel with uranium-235 enrichment of 3.11 percent and 39.65 gigawatt-days per MTHM burnup. Using this method, 100 percent of the total inventory of high-level radioactive waste inventory could be disposed of in the repository within the 4,667 MTHM allocation for high-level radioactive waste.

Radiotoxicity Method. Yet another method, the radiotoxicity method, uses a comparison of the relative radiotoxicity of defense high-level radioactive waste to that of a standard MTHM of commercial spent nuclear fuel, and is thus considered an extension of the total radioactivity method. Radiotoxicity compares the inventory of specific radionuclides to a regulatory release limit for that radionuclide, and uses these relationships to develop an overall radiotoxicity index. For this equivalence, the standard spent nuclear fuel characteristics are based on pressurized-water reactor fuel with uranium-235 enrichment of 3.11 percent, 39.65 gigawatt-days per MTHM burnup. Using this method, 100 percent of the total inventory of high-level radioactive waste could be disposed of in the repository within the 4,667 MTHM allocation for high-level radioactive waste.

A recent report (DIRS 103495-Knecht et al. 1999, all) describes four equivalence calculation methods and notes that, under the Total Radioactivity Method or the Radiotoxicity Method, all DOE high-level radioactive waste could be disposed of under the Proposed Action. Using different equivalence methods would shift the proportion of high-level radioactive waste that could be disposed of between the Proposed Action and Inventory Module 1 analyzed in Chapter 8, but would not change the cumulative impacts analyzed in this EIS. Regardless of the equivalence method used, the EIS analyzes the impacts from disposal of the entire inventory of high-level radioactive waste in inventory Module 1.

A.2.3.2 Sources

A.2.3.2.1 *Hanford Site*

The Hanford high-level radioactive waste materials discussed in this EIS include tank waste, strontium capsules, and cesium capsules (DIRS 104406-Picha 1997, Table RL-1). DOE has not declared other miscellaneous materials or waste at Hanford, either existing or forecasted, to be candidate high-level radioactive waste streams. Before shipment to the repository, DOE would vitrify the high-level radioactive waste into a borosilicate glass matrix and pour it into stainless-steel canisters.

A.2.3.2.2 *Idaho National Engineering and Environmental Laboratory*

The Idaho National Engineering and Environmental Laboratory has proposed three different high-level radioactive waste stream matrices for disposal at the proposed Yucca Mountain Repository—glass, ceramic, and metal. The glass matrix waste stream would come from the Idaho Nuclear Technology and Engineering Center and would consist of wastes generated from the treatment of irradiated nuclear fuels. The ongoing Argonne National Laboratory-West electrometallurgical treatment of DOE sodium-bonded fuels will generate both ceramic and metallic high-level radioactive waste matrices. DOE is developing the *Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement* (see DIRS 155100-DOE 1999, all), to support decisions on managing the high-level radioactive waste at the Idaho Nuclear Technology and Engineering Center.

A.2.3.2.3 *Savannah River Site*

Savannah River Site high-level radioactive waste consists of wastes generated from the treatment of irradiated nuclear fuels. These wastes include various chemicals, radionuclides, and fission products that DOE maintains in liquid, sludge, and saltcake forms. The Defense Waste Processing Facility at the Savannah River Site mixes the high-level radioactive waste with glass-forming materials, converts it to a durable borosilicate glass waste form, pours it into stainless-steel canisters, and seals the canisters with welded closure plugs (DIRS 104406-Picha 1997, Attachment 4, p. 2).

Another source of high-level radioactive waste at the Savannah River Site is the immobilized plutonium addressed in Section A.2.4.

A.2.3.2.4 *West Valley Demonstration Project*

The West Valley Demonstration Project is responsible for solidifying high-level radioactive waste that remains from the commercial spent nuclear fuel reprocessing plant operated by Nuclear Fuel Services. The Project mixes the high-level radioactive waste with glass-forming materials, converts it to a durable borosilicate glass waste form, pours it into stainless-steel canisters, and seals the canisters with welded closure plugs.

A.2.3.3 Present Status

A.2.3.3.1 *Hanford Site*

The Hanford Site stores high-level radioactive waste in underground carbon-steel tanks. This analysis assumed that before vitrification, strontium and cesium capsules currently stored in water basins at Hanford would be blended with the liquid high-level radioactive waste. To date, Hanford has immobilized no high-level radioactive waste. Before shipping waste to a repository, DOE would vitrify it into an acceptable glass form. DOE has scheduled vitrification to begin in 2007 with an estimated completion in 2028.

A.2.3.3.2 *Idaho National Engineering and Environmental Laboratory*

Most of the high-level radioactive waste at the Idaho Nuclear Technology and Engineering Center (formerly the Idaho Chemical Processing Plant) is in calcined solids (calcine) stored at the Idaho National Engineering and Environmental Laboratory. The calcine, an interim waste form, is in stainless-steel bins in concrete vaults. Before shipment to a repository, DOE proposes to immobilize the high-level radioactive waste in a vitrified (glass) waste form. The Idaho Nuclear Technology and Engineering Center proposes to implement its vitrification program in 2020 and complete it in 2035 (DIRS 103497-INEEL 1998, pp. A-39 to A-42).

As discussed in Section A.2.2.1, Argonne National Laboratory-West began electrometallurgical treatment of EBR-II reactor fuel in 2000. The ceramic and metallic waste forms being produced will be stored onsite.

A.2.3.3.3 *Savannah River Site*

DOE stores high-level radioactive waste in underground tanks at the Savannah River Site. High-level radioactive waste that has been converted to a borosilicate glass form and DOE projects completion of the vitrification of the stored high-level radioactive waste by 2027 (DIRS 157008-DOE 2001, all).

A.2.3.3.4 *West Valley Demonstration Project*

High-level radioactive waste is stored in underground tanks at the West Valley site. High-level radioactive waste that has been converted into a borosilicate glass waste form is stored onsite. West Valley plans to complete its vitrification program by the Fall of 2002 (DIRS 102588-DOE 1992, Chapter 3).

A.2.3.4 Final Waste Form

The final waste form for high-level radioactive waste from the Hanford Site, Savannah River Site, Idaho Nuclear Technology and Engineering Center, and West Valley Demonstration Project would be a vitrified glass matrix in a stainless-steel canister.

The waste forms from Argonne National Laboratory-West will be ceramic and metallic waste matrices and will be in stainless-steel canisters similar to those used for Savannah River Site and Idaho Nuclear Technology and Engineering Center glass wastes.

A.2.3.5 Waste Characteristics

A.2.3.5.1 *Mass and Volume*

Hanford Site. The estimated volume of borosilicate glass generated by high-level radioactive waste disposal actions at Hanford will be 15,700 cubic meters (554,000 cubic feet); the estimated mass of the glass is 44,000 metric tons (48,500 tons) (DIRS 104407-Picha 1998, Attachment 1). The volume calculation assumes that strontium and cesium compounds from capsules currently stored in water basins would be blended with tank wastes before vitrification with no increase in product volume. This volume of glass could require as many as 14,500 canisters, nominally 4.5 meters (15 feet) long with a 0.61-meter (2-foot) diameter (DIRS 104407-Picha 1998, Attachment 1).

Idaho National Engineering and Environmental Laboratory. Table A-26 lists the volumes, masses, densities, and estimated number of canisters for the three proposed waste streams.

Savannah River Site. Based on Revision 8 of the High-Level Waste System Plan (DIRS 101904-Davis and Wells 1997, all), the Savannah River Site would generate an estimated 5,978 canisters of high-level radioactive waste (DIRS 104406-Picha 1997, Attachment 1). The canisters have a nominal outside diameter of 0.61 meter (2 feet) and a nominal height of 3 meters (10 feet). They would contain a total of approximately 4,240 cubic meters (150,000 cubic feet) of glass. The estimated total mass of high-level radioactive waste for repository disposal would be 11,600 metric tons (12,800 tons) (DIRS 104406-Picha 1997, Attachment 1). DOE has addressed the additional high-level radioactive waste canisters that DOE

Table A-26. Physical characteristics of high-level radioactive waste at the Idaho National Engineering and Environmental Laboratory.[a,b]

Physical quantities	INTEC glass matrix	ANL-W ceramic matrix	ANL-W metal matrix
Volume (cubic meters)[c]	743	60.0	1.2
Mass (kilograms)[d]	1,860,000	144,000	9,000
Density (kilograms per cubic meter)	2,500	2,400	7,750
Number of canisters [range][e]	1,190	96 [80 - 125]	6 [2 - 10]

a. Sources: DIRS 104406-Picha (1997, Attachment 1, Table ID-2); DIRS 104389-Goff (1998, all); DIRS 104392-Goff (1998, all).
b. INTEC = Idaho Nuclear Technology and Engineering Center; ANL-W = Argonne National Laboratory-West.
c. To convert cubic meters to cubic yards, multiply by 1.3079.
d. To convert kilograms to pounds, multiply by 2.2046.
e. Canister would be nominally 3 meters (10 feet) by 0.61 meter (2 feet). Canisters would be filled to approximately 0.625 cubic meter (22 cubic feet).

would generate at the Savannah River Site as a result of immobilizing surplus plutonium (DIRS 118979-DOE 1999, p. 2-29). As discussed in DIRS 118979-DOE (1999, p. 2-29), 101 additional canisters would be required if the assumed one-third of the plutonium is immobilized. If the entire inventory of surplus plutonium was immobilized, 272 additional high-level radioactive waste canisters would be required.

West Valley Demonstration Project. The West Valley Demonstration Project will generate between 260 and 300 canisters of high-level radioactive waste. The canisters have a nominal outside diameter of 0.61 meter (2 feet) and a nominal height of 3 meters (10 feet) (DIRS 104406-Picha 1997, Attachment 1). They will contain approximately 200 cubic meters (7,060 cubic feet) of glass. The estimated total mass of this high-level radioactive waste will be between 540 and 630 metric tons (595 and 694 tons) (DIRS 104413-Picha 1998, p. 3).

Summary. Table A-27 summarizes the information in the previous paragraphs to provide the estimated total mass and volume projected to be disposed of at the repository.

Table A-27. High-level radioactive waste mass and volume summary.

Parameter	Total[a,b]
Mass	58,000 metric tons
Volume	21,000 cubic meters
Number of canisters	22,147 - 22,280[c]

a. Sources: DIRS 104406-Picha (1997, Attachment 1); DIRS 104407-Picha (1998, Attachment 1).
b. To convert metric tons to tons, multiply by 1.1023; to convert cubic meters to cubic yards, multiply by 1.3079.
c. The number of canisters depends on the amount of surplus weapons-usable plutonium immobilized (see Section A.2.4.5.2.1).

A.2.3.5.2 *Amount and Nature of Radioactivity*

The following paragraphs present radionuclide inventory information for the individual sites. They present the best available data at varying dates; however, in most cases, the data are conservative because the inventories are for dates earlier than the date of disposal, and additional radioactive decay would occur before disposal. Any differences due to varying amounts of radioactive decay are small.

Hanford Site. Table A-28 lists the estimated radionuclide inventory for Hanford high-level radioactive glass waste, including strontium-90 and cesium-137 currently stored in capsules (DIRS 104406-Picha 1997, Table RL-1). With the exception of hydrogen-3 and carbon-14, this table makes the conservative assumption that 100 percent of a radionuclide in Hanford's 177 tanks and existing capsules is vitrified.

Table A-28. Radionuclide distribution for Hanford Site high-level radioactive waste.[a,b]

Radionuclide[c]	Total curies	Curies per canister	Radionuclide	Total curies	Curies per canister
Hydrogen-3	--[d]	--	Thorium-229	1.8	1.3×10^{-4}
Carbon-14	9.6×10^{-2}	6.6×10^{-6}	Thorium-230	--	--
Chlorine-36	--	--	Thorium-232	2.1	1.5×10^{-4}
Nickel-59	9.3×10^{2}	6.4×10^{-2}	Protactinium-231	1.6×10^{2}	1.1×10^{-2}
Nickel-63	9.2×10^{4}	6.3	Uranium-232	1.2×10^{2}	8.5×10^{-3}
Cobalt-60	1.2×10^{4}	8.5×10^{-1}	Uranium-233	4.8×10^{2}	3.3×10^{-2}
Selenium-79	7.7×10^{2}	5.3×10^{-2}	Uranium-234	3.5×10^{2}	2.4×10^{-2}
Krypton-85	--	--	Uranium-235	1.5×10^{1}	1.0×10^{-3}
Strontium-90	9.7×10^{7}	6.7×10^{3}	Uranium-236	9.6	6.6×10^{-4}
Niobium-93m	2.7×10^{3}	1.9×10^{-1}	Uranium-238	3.2×10^{2}	2.2×10^{-2}
Niobium-94	--	--	Neptunium-237	1.4×10^{2}	9.7×10^{-3}
Zirconium-93	3.6×10^{3}	2.5×10^{1}	Plutonium-238	2.1×10^{3}	1.9×10^{-1}
Technetium-99	3.3×10^{4}	2.3	Plutonium-239	4.7×10^{4}	2.7
Rhodium-101	--	--	Plutonium-240	9.9×10^{3}	6.2×10^{-1}
Rhodium-102	--	--	Plutonium-241	2.3×10^{5}	1.6×10^{1}
Ruthenium-106	1.0×10^{5}	7.2	Plutonium-242	1.2	8.0×10^{-5}
Palladium-107	--	--	Americium-241	7.0×10^{4}	4.8
Tin-126	1.2×10^{3}	8.2×10^{-2}	Americium-242m	--	--
Iodine-129	3.2×10^{1}	2.2×10^{-3}	Americium-243	9.3	6.4×10^{-4}
Cesium-134	8.9×10^{4}	6.1	Curium-242	7.7×10^{1}	5.3×10^{-3}
Cesium-135	--	--	Curium-243	1.0×10^{1}	6.9×10^{-4}
Cesium-137	1.1×10^{8}	7.7×10^{3}	Curium-244	2.4×10^{2}	1.7×10^{-2}
Samarium-151	2.8×10^{6}	1.9×10^{2}	Curium-245	--	--
Lead-210	--	--	Curium-246	--	--
Radium-226	6.3×10^{-2}	4.4×10^{-6}	Curium-247	--	--
Radium-228	7.7×10^{1}	5.3×10^{-3}	Curium-248	--	--
Actinium-227	8.8×10^{1}	6.0×10^{-3}	Californium-252	--	--

a. Sources: DIRS 104406-Picha (1997, Table RL-1); DIRS 104407-Picha (1998, Attachment 1).
b. Decayed to January 1, 1994.
c. Half-lives are listed in Tables A-11 and footnote g of Table A-21, with the exception of lead-210 = 23 years, rhodium-101 = 3.3 years, radium-226 = 1.6×10^{3} years, and radium 228 = 5.7 years.
d. -- = not found in appreciable quantities.

Consistent with Hanford modeling for the Integrated Data Base (DIRS 101815-DOE 1997, p. 2-24), pretreatment and vitrification would separate hydrogen-3 and carbon-14 from the high-level radioactive waste stream such that essentially 0.0 percent and 0.002 percent of each, respectively, would be present in the glass. A large portion of iodine-129 could also be separated, but the analysis assumed a conservative 50-percent retention (DIRS 104407-Picha 1998, Attachment 1). Table A-28 uses the estimated number of canisters (14,500) to develop the curies-per-canister value.

Idaho National Engineering and Environmental Laboratory. Table A-29 contains a baseline radionuclide distribution for the three Idaho National Engineering and Environmental Laboratory high-level radioactive waste streams. For each waste stream, the total radionuclide inventory is provided, as is the worst-case value for curies per canister. For Idaho Nuclear Technology and Engineering Center glass, the calculated inventories are decayed to 2035. For Argonne National Laboratory-West waste matrices, the calculated inventories are decayed to 2000.

Savannah River Site. The Waste Qualification Report details the projected radionuclide distribution in the high-level radioactive waste from the Savannah River Site (DIRS 101908-Plodinec and Marra 1994, p. 10). Table A-30 lists the quantities of individual radionuclides decayed to 2015. The curie-per-canister values were obtained by dividing the total radionuclide projection by the expected number of canisters (5,978).

Table A-29. Radionuclide distribution for Idaho National Engineering and Environmental Laboratory high-level radioactive waste.[a,b]

	INTEC glass		ANL-W ceramic[d]		ANL-W metal[d]	
Radionuclides[c]	Total curies for 2035	Curies per canister[d]	Total curies for 2000	Curies per canister[e]	Total curies for 2000	Curies per canister[e]
Hydrogen-3	3.6×10^{3}	4.3	--[f]	--	--	--
Carbon-14	2.8×10^{-2}	8.3×10^{-5}	--	--	4.3	4.3
Chlorine-36	--	--	--	--	--	--
Cobalt-60	3.2×10^{1}	3.6×10^{-2}	--	--	3.2×10^{3}	3.2×10^{3}
Nickel-59	--	--	--	--	1.1×10^{1}	1.1×10^{1}
Nickel-63	--	--	--	--	4.1×10^{2}	3.9×10^{2}
Selenium-79	--	--	--	--	--	--
Krypton-85	--	--	--	--	--	--
Strontium-90	7.0×10^{6}	1.2×10^{4}	7.1×10^{5}	4.7×10^{4}	--	--
Niobium-93	4.7×10^{2}	1.4	--	--	2.9×10^{1}	2.9×10^{1}
Niobium-94	5.4×10^{-3}	1.6×10^{-5}	--	--	2.7	2.7
Zirconium-93	--	--	--	--	--	--
Technetium-99	3.4×10^{3}	9.9	--	--	1.3×10^{2}	1.3×10^{2}
Rhodium-101	--	--	--	--	--	--
Rhodium-102	2.0×10^{-5}	2.2×10^{-8}	--	--	--	--
Ruthenium-106	1.0×10^{-9}	8.7×10^{-13}	--	--	2.1×10^{4}	2.1×10^{4}
Palladium-107	--	--	--	--	--	--
Tin-126	8.9×10^{1}	2.6×10^{-1}	--	--	2.8	2.1
Iodine-129	5.6	1.7×10^{-2}	3.4×10^{-1}	1.8×10^{-2}	--	--
Cesium-134	3.3×10^{-2}	3.6×10^{-5}	7.9×10^{3}	5.1×10^{2}	--	--
Cesium-135	1.6×10^{2}	2.5×10^{-1}	1.6×10^{1}	8.8×10^{-1}	--	--
Cesium-137	6.0×10^{6}	1.2×10^{4}	8.5×10^{5}	5.3×10^{4}	--	--
Samarium-151	--	--	--	--	--	--
Lead-210	--	--	--	--	--	--
Radium-226	9.7×10^{-3}	7.2×10^{-5}	3.0×10^{-5}	2.1×10^{-6}	--	--
Radium-228	--	--	--	--	--	--
Actinium-227	--	--	--	--	--	--
Thorium-229	--	--	--	--	--	--
Thorium-230	4.0×10^{-1}	2.8×10^{-3}	4.7×10^{-3}	8.9×10^{-4}	--	--
Thorium-232	9.9×10^{-8}	5.0×10^{-10}	2.3×10^{-9}	1.3×10^{-10}	--	--
Protactinium-231	--	--	--	--	--	--
Uranium-232	4.6×10^{-3}	5.2×10^{-6}	2.6×10^{-3}	1.8×10^{-4}	1.2×10^{-4}	1.2×10^{-4}
Uranium-233	1.3×10^{-3}	6.1×10^{-6}	2.0×10^{-4}	1.4×10^{-5}	5.8×10^{-5}	5.8×10^{-5}
Uranium-234	1.0×10^{2}	1.1×10^{-1}	2.8	1.9×10^{-1}	7.7×10^{-1}	7.7×10^{-1}
Uranium-235	5.9×10^{-1}	6.6×10^{-4}	8.8×10^{-2}	5.9×10^{-3}	2.5×10^{-2}	2.5×10^{-2}
Uranium-236	1.5	1.7×10^{-3}	6.3×10^{-2}	4.2×10^{-3}	1.8×10^{-2}	1.8×10^{-2}
Uranium-238	2.9×10^{-2}	3.3×10^{-5}	2.8×10^{-1}	4.9×10^{-3}	9.7×10^{-2}	8.8×10^{-2}
Neptunium-237	6.3	2.8×10^{-2}	1.3	5.8×10^{-2}	2.4×10^{-5}	2.3×10^{-5}
Plutonium-238	9.0×10^{4}	1.0×10^{2}	3.6×10^{2}	2.9×10^{1}	6.6×10^{-3}	6.6×10^{-3}
Plutonium-239	1.8×10^{3}	2.0	1.7×10^{4}	8.1×10^{2}	3.3×10^{-1}	3.3×10^{-1}
Plutonium-240	1.6×10^{3}	1.8	1.5×10^{3}	6.9×10^{1}	2.9×10^{-2}	2.9×10^{-2}
Plutonium-241	1.9×10^{4}	2.2×10^{1}	1.1×10^{4}	1.3×10^{3}	1.9×10^{-1}	1.9×10^{-1}
Plutonium-242	3.4	3.8×10^{-3}	1.2×10^{-1}	2.3×10^{-2}	2.0×10^{-6}	2.0×10^{-6}
Americium-241	1.3×10^{4}	1.4×10^{1}	1.6×10^{3}	3.4×10^{1}	3.1×10^{-2}	2.1×10^{-2}
Americium-242/242m	1.5×10^{-2}	9.4×10^{-5}	1.4×10^{1}	2.1×10^{-1}	2.7×10^{-4}	2.1×10^{-4}
Americium-243	1.4×10^{-2}	1.1×10^{-4}	2.8×10^{-1}	1.9×10^{-2}	4.8×10^{-6}	4.8×10^{-6}
Curium-242	1.2×10^{-2}	7.7×10^{-5}	1.2×10^{1}	1.8×10^{-1}	2.3×10^{-4}	1.8×10^{-4}
Curium-243	4.7×10^{-4}	3.4×10^{-6}	1.6×10^{-1}	3.1×10^{-3}	3.0×10^{-6}	2.1×10^{-6}
Curium-244	1.0×10^{-2}	7.7×10^{-5}	1.9	1.3×10^{-1}	3.1×10^{-5}	3.1×10^{-5}
Curium-245	3.7×10^{-6}	2.8×10^{-8}	6.8×10^{-5}	4.7×10^{-6}	1.1×10^{-9}	1.1×10^{-9}
Curium-246	8.7×10^{-8}	6.6×10^{-10}	4.2×10^{-7}	2.9×10^{-8}	7.1×10^{-12}	7.1×10^{-12}
Curium-247	3.1×10^{-14}	2.4×10^{-16}	2.4×10^{-13}	1.6×10^{-14}	4.0×10^{-18}	4.0×10^{-18}
Curium-248	9.4×10^{-15}	7.2×10^{-17}	2.6×10^{-14}	1.8×10^{-15}	4.4×10^{-19}	4.4×10^{-19}
Californium-252	--	--	6.5×10^{-19}	1.6×10^{-19}	--	--

a. Sources: DIRS 104406-Picha (1997, Table ID-2); DIRS 104389-Goff (1998, all).
b. INTEC = Idaho Nuclear Technology and Engineering Center; ANL-W = Argonne National Laboratory-West.
c. Half-lives are listed in Tables A-11, footnote g of Table A-21, and footnote c of Table A-28.
d. Matrices based on treating all sodium-bonded fuels. Curie values based on calculated data from stored material.
e. Curie per canister values were provided as worst case rather than a homogenous mixture.
f. -- = not found in appreciable quantities.

Table A-30. Radionuclide distribution for Savannah River Site high-level radioactive waste (2015).[a]

Radionuclide[b]	Total (curies)	Curies per canister	Radionuclide	Total (curies)	Curies per canister
Hydrogen-3	--[c]	--	Thorium-229	--	--
Carbon-14	--	--	Thorium-230	2.4×10^{-2}	4.0×10^{-6}
Chlorine-36	--	--	Thorium-232	--	--
Nickel-59	1.1×10^{2}	1.8×10^{-2}	Protactinium-231	--	--
Nickel-63	1.2×10^{4}	2.1	Uranium-232	--	--
Cobalt-60[c]	--	4.5×10^{1}	Uranium-233	--	--
Selenium-79	1.1×10^{3}	1.8×10^{-1}	Uranium-234	1.6×10^{2}	2.7×10^{-2}
Krypton-85	--	--	Uranium-235	--	--
Strontium-90	1.7×10^{8}	2.9×10^{4}	Uranium-236	--	--
Niobium-93m	1.3×10^{4}	2.2	Uranium-238	5.0×10^{1}	8.3×10^{-3}
Niobium-94	--	--	Neptunium-237	4.1×10^{2}	6.8×10^{-2}
Zirconium-93	3.0×10^{4}	5.0	Plutonium-238	3.0×10^{6}	5.0×10^{2}
Technetium-99	1.5×10^{4}	2.5	Plutonium-239	3.7×10^{4}	6.2
Rhodium-101	--	--	Plutonium-240	2.5×10^{4}	4.1
Rhodium-102	--	--	Plutonium-241	3.3×10^{6}	5.4×10^{2}
Ruthenium-106[d]	--	2.4	Plutonium-242	3.5×10^{1}	5.8×10^{-3}
Palladium-107	7.3×10^{1}	1.2×10^{-2}	Americium-241	1.6×10^{5}	2.6×10^{1}
Tin-126	2.6×10^{3}	4.3×10^{-1}	Americium-242m	--	--
Iodine-129	--	--	Americium-243	1.1×10^{3}	1.8×10^{-1}
Cesium-134[d]	--	1.2×10^{1}	Curium-242	--	--
Cesium-135	4.0×10^{2}	6.7×10^{-2}	Curium-243	--	--
Cesium-137	1.5×10^{8}	2.4×10^{4}	Curium-244	4.9×10^{5}	8.3×10^{1}
Samarium-151	3.3×10^{6}	5.5×10^{2}	Curium-245	--	--
Lead-210	--	--	Curium-246	--	--
Radium-226	--	--	Curium-247	--	--
Radium-228	--	--	Curium-248	--	--
Actinium-227	--	--	Californium-252	--	--

a. Sources: DIRS 101908-Plodinec and Marra (1994, p. 10); DIRS 104403-Pearson (1998, all).
b. Half-lives are listed in Tables A-11, footnote g of Table A-21, and footnote c of Table A-28.
c. -- = not found in appreciable quantities.
d. Total curie content not provided for these nuclides; curie per canister values provided for 10 years after production.

West Valley Demonstration Project. DOE used the ORIGEN2 computer code to estimate the radionuclide inventory for the West Valley Demonstration Project, simulating each Nuclear Fuel Services irradiated fuel campaign. A detailed description of the development of these estimates is in the West Valley Demonstration Project Waste Qualification Report (DIRS 103500-WVNS n.d., WQR-1.2, Appendix 1, Rev. 1). Table A-31 lists the estimated activity by nuclide and provides the total curies, as well as the curies per canister, based on 260 canisters.

A.2.3.5.3 *Chemical Composition*

Hanford Site. The Integrated Data Base (DIRS 101815-DOE 1997, p. 2-29) provides the best available information for the proposed representative chemical composition of future high-level radioactive waste glass from Hanford. Table A-32 combines the percentages by weight of chemical constituents obtained from the Integrated Data Base with the estimated mass to present the expected chemical composition of the glass in terms of mass per chemical compound.

Idaho National Engineering and Environmental Laboratory

Idaho Nuclear Technology and Engineering Center Glass Matrix. This waste stream is composed of three primary sources—zirconium calcine, aluminum calcine, and sodium-bearing waste.

Table A-31. Radionuclide distribution for West Valley Demonstration Project high-level radioactive waste (2015).[a]

Radionuclide[b]	Total curies	Curies per canister	Radionuclide	Total curies	Curies per canister
Hydrogen-3	2.0×10^{1}	7.8×10^{-2}	Thorium-229	2.3×10^{-1}	8.9×10^{-4}
Carbon-14	1.4×10^{2}	5.3×10^{-1}	Thorium-230	6.0×10^{-2}	2.3×10^{-4}
Chlorine-36	--[c]	--	Thorium-232	1.6	6.3×10^{-3}
Nickel-59	1.1×10^{2}	4.1×10^{-1}	Protactinium-231	1.5×10^{1}	5.9×10^{-2}
Nickel-63	7.1×10^{3}	2.7×10^{1}	Uranium-232	5.9	2.3×10^{-2}
Cobalt-60	2.9×10^{1}	1.1×10^{-1}	Uranium-233	9.5	3.7×10^{-2}
Selenium-79	6.0×10^{1}	2.3×10^{-1}	Uranium-234	5.0	1.9×10^{-2}
Krypton-85	--	--	Uranium-235	1.0×10^{-1}	3.9×10^{-4}
Strontium-90	3.7×10^{6}	1.4×10^{4}	Uranium-236	3.0×10^{-1}	1.1×10^{-3}
Niobium-93m	2.5×10^{2}	9.5×10^{-1}	Uranium-238	8.5×10^{-1}	3.3×10^{-3}
Niobium-94	--	--	Neptunium-237	2.4×10^{1}	9.2×10^{-2}
Zirconium-93	2.7×10^{2}	1.1	Plutonium-238	7.0×10^{3}	2.7×10^{1}
Technetium-99	1.7×10^{3}	6.5	Plutonium-239	1.7×10^{3}	6.4
Rhodium-101	--	--	Plutonium-240	1.2×10^{3}	4.7
Rhodium-102	--	--	Plutonium-241	2.5×10^{4}	9.5×10^{1}
Ruthenium-106	5.0×10^{-7}	1.9×10^{-9}	Plutonium-242	1.7	6.4×10^{-3}
Palladium-107	1.1×10^{1}	4.2×10^{-2}	Americium-241	5.3×10^{4}	2.0×10^{2}
Tin-126	1.0×10^{2}	4.0×10^{-1}	Americium-242m	2.7×10^{2}	1.0
Iodine-129	2.1×10^{-1}	8.1×10^{-4}	Americium-243	3.5×10^{2}	1.3
Cesium-134	1.2	4.4×10^{-3}	Curium-242	2.2×10^{2}	8.4×10^{-1}
Cesium-135	1.6×10^{2}	6.2×10^{-1}	Curium-243	7.3×10^{1}	2.8×10^{-1}
Cesium-137	4.1×10^{6}	1.6×10^{4}	Curium-244	2.9×10^{3}	1.1×10^{1}
Samarium-151	7.0×10^{4}	2.7×10^{2}	Curium-245	8.8×10^{-1}	3.4×10^{-3}
Lead-210	--	--	Curium-246	1.0×10^{-1}	3.9×10^{-4}
Radium-226	--	--	Curium-247	--	--
Radium-228	1.6	6.3×10^{-3}	Curium-248	--	--
Actinium-227	1.2×10^{1}	4.6×10^{-2}	Californium-252	--	--

a. Source: DIRS 103500-WVNS (n.d., WQR-1.2, Appendix 1, Rev. 1).
b. Half-lives are listed in Tables A-11, A-21, and A-28.
c. -- = not found in appreciable quantities.

Table A-32. Expected chemical composition of Hanford high-level radioactive waste glass (kilograms).[a,b]

Compound	Mass	Compound	Mass
Aluminum oxide	4,100,000	Sodium oxide	5,190,000
Boron oxide	3,090,000	Sodium sulfate	44,000
Bismuth trioxide	510,000	Nickel monoxide	480,000
Calcium oxide	370,000	Phosphorous pentaoxide	690,000
Ceric oxide	500,000	Lead monoxide	62,000
Chromic oxide	160,000	Silicon oxide	20,300,000
Ferric oxide	1,980,000	Strontium oxide	79,000
Potassium oxide	75,000	Thorium dioxide	4,400
Lanthanum oxide	48,000	Uranium oxide	2,940,000
Lithium oxide	880,000	Zirconium dioxide	1,630,000
Manganese dioxide	510,000	Other	75,000
Sodium fluoride	280,000	***Total***	***44,000,000***

a. Sources: DIRS 101815-DOE (1997, p. 2-29); DIRS 104407-Picha (1998, Attachment 1).
b. To convert kilograms to pounds, multiply by 2.2046.

The distribution of these sources is 55 percent, 15 percent, and 30 percent, respectively (DIRS 104395-Heiser 1998, all). Table A-33 lists the chemical composition of the total waste stream.

Table A-33. Expected glass matrix chemical composition at Idaho Nuclear Technology and Engineering Center (kilograms).[a,b]

Compound or element	Mass	Compound or element	Mass
Aluminum oxide	130,000	Silicon oxide	1,020,000
Ammoniummolybdophosphate	26,000	Zirconium dioxide	18,000
Boron oxide	200,000	Arsenic	100
Calcium fluoride	140,000	Cadmium	42,000
Calcium oxide	4,100	Chromium	14,000
Ceric oxide	300	Mercury[c]	200
Ferric oxide	800	Nickel	1,400
Sodium oxide	250,000	Lead	1,800
Phosphorous pentaoxide	1,000	***Total***[d]	***1,860,000***

a. Sources: DIRS 104406-Picha (1997, Table ID-3); DIRS 104395-Heiser (1998, all).
b. Masses are rounded to the nearest 100 kilograms; to convert kilograms to pounds, multiply by 2.2046.
c. Assumes only 0.1 percent capture of original mercury in the feed materials.
d. Trace amounts of antimony, beryllium, barium, selenium, silver, and thallium were also reported.

Argonne National Laboratory-West Ceramic and Metal Matrices. Electrometallurgical processing of DOE spent nuclear fuel containing thermal-bond sodium results in two high-level radioactive waste forms for repository disposal. The first form is a glass-bonded ceramic composite. It stabilizes the alkali, alkaline earth, lanthanide, halide, and transuranic materials in processed spent nuclear fuel. These elements are present as halides after fuel treatment. For disposal, these compounds are stabilized in a zeolite-based material (DIRS 104389-Goff 1998, all).

The chemical formula for zeolite-4A, the typical starting material, is $Na_{12}[(AlO_2)_{12}(SiO_2)_{12}]$. In the waste form, zeolite contains approximately 10 to 12 percent of the halide compounds by weight. The zeolite mixture typically is combined with 25-percent glass frit by weight, placed in a stainless-steel container, and processed into a solid monolith. The zeolite is converted to the mineral sodalite in the process (DIRS 104389-Goff 1998, all). Table A-34 lists the composition of the waste form.

Table A-34. Ceramic waste matrix chemical composition at Argonne National Laboratory-West (kilograms).[a,b]

Component	Mass	Component	Mass
Zeolite-4A	92,000	Potassium iodide	10
Silicon oxide	24,000	Cesium chloride	160
Boron oxide	6,800	Barium chloride	70
Aluminum oxide	2,500	Lanthium chloride	90
Sodium oxide	2,700	Ceric chloride	140
Potassium oxide	140	Praseodymium chloride	70
Lithium-potassium chloride	13,000	Neodymium chloride	240
Sodium chloride	980	Samarium chloride	40
Rubidium chloride	20	Yttrium chloride	60
Strontium chloride	70	***Total***[c]	***144,000***

a. Source: DIRS 104389-Goff (1998, all), DIRS 104392-Goff (1998, all).
b. To convert kilograms to pounds, multiply by 2.2046.
c. Includes trace amounts of potassium bromide and europium chloride.

The halide composition would depend on the fuel processed. The final bulk composition of the ceramic waste form by weight percentages would be 25 percent glass, 63 to 65 percent zeolite-4A, and 10 to 12 percent halide salts.

Table A-35 lists the estimated composition of the second high-level radioactive waste form, which is a metal matrix waste form. The table combines percentage weight distribution with the total expected mass of the metal waste form to achieve a distributed mass by element (DIRS 104389-Goff 1998, all).

Table A-35. Expected metal waste matrix chemical composition at Argonne National Laboratory-West (kilograms).[a]

Component	Mass
Iron	4,200
Chromium	1,500
Nickel	1,100
Manganese	180
Molybdenum	220
Silicon	90
Zirconium	1,400
NMFPs[b]	360
Others[c]	20
Total	***9,000***

a. Source: DIRS 104389-Goff (1998, all); to convert kilograms to pounds, multiply by 2.2046.
b. NMFPs = Noble metal fission products; includes silver, niobium, palladium, rhodium, ruthenium, antimony, tin, tantalum, technetium, and cobalt in small amounts.
c. Others include trace amounts of carbon, phosphorus, and sulfur.

Savannah River Site. Fowler et al. (DIRS 101829-1995, p. 4) describes the chemical composition of the Defense Waste Processing Facility glass in detail. Table A-36 lists the distributed mass of the chemical constituents that comprise the current design-basis glass for the Savannah River Site. These values are based on a total mass of the glass of 11,600 metric tons (12,800 tons) (DIRS 104406-Picha 1997, Attachment 1).

West Valley Demonstration Project. The West Valley Demonstration Project will produce a single type of vitrified high-level radioactive waste. West Valley Nuclear Services Company provides a target composition for all chemical constituents in the high-level radioactive waste (DIRS 103500-WVNS n.d., WQR-1.1, Rev. 1, p. 7). Table A-37 lists the expected chemical composition based on this target composition and the upper range of the projected total glass mass, 630 metric tons (694 tons).

A.2.3.5.4 *Thermal Output*

Hanford Site. The estimated total thermal power from radioactive decay in the 14,500 reference canisters would be 1,190 kilowatts (as of January 1, 1994). This total heat load equates to an average power of 82 watts per canister. These values represent the hypothetical situation in which washed sludges from 177 tanks, cesium concentrates from the decontamination of low-level supernates, and strontium and cesium materials from capsules would be uniformly blended before vitrification. Realistically, uniform blending would not be likely. Current planning calls for merging all capsule materials with tank wastes from 2013 through 2016, which would create much hotter canisters during these years. In the extreme, the nonuniform blending of cesium concentrates and capsule materials into a relatively small volume of sludge waste could produce a few canisters with specific powers as high as 1,500 watts, which is the expected maximum for the nominally 4.5-meter (15-foot) Hanford canisters in the Civilian Radioactive Waste Management System Baseline (DIRS 104406-Picha 1997, Attachment 1, p. 2; DIRS 104476-Taylor 1997, all).

Idaho National Engineering and Environmental Laboratory. The Laboratory has three proposed high-level radioactive waste streams. Table A-38 lists the thermal output of these waste streams per waste canister.

Table A-36. Expected Savannah River Site high-level radioactive waste chemical composition (kilograms).[a,b]

Glass component	Mass	Glass component	Mass
Aluminum oxide	460,000	Sodium chloride	22,000
Barium sulfate	31,000	Neodymium	13,000
Calcium oxide	110,000	Nickel monoxide	100,000
Calcium sulfate	9,300	Neptunium	100
Cadmium	140	Promethium	210
Cerium	6,800	Praseodymium	3,300
Chromic oxide	14,000	Rubidium	120
Cesium oxide	14,000	Selenium	270
Copper oxide	51,000	Silicon oxide	5,800,000
Europium	200	Samarium	2,200
Ferric oxide	1,200,000	Tin	120
Potassium oxide	450,000	Tellurium	2,200
Lanthanum	3,500	Thorium dioxide	22,000
Lithium oxide	510,000	Titanium dioxide	100,000
Magnesium oxide	160,000	Uranium oxide	250,000
Manganese oxide	230,000	Zirconium	13,000
Molybdenum	14,000	Other[c]	58,000
Sodium oxide	1,000,000		
Sodium sulfate	12,000	***Total***	***11,600,000***

a. Sources: DIRS 101829-Fowler et al. (1995, p. 4); DIRS 104406-Picha (1997, Attachment 1).
b. To convert kilograms to pounds, multiply by 2.2046.
c. Includes trace amounts of silver, americium, cobalt, and antimony.

Table A-37. Expected West Valley Demonstration Project chemical composition (kilograms).[a,b]

Compound	Mass	Compound	Mass
Aluminum oxide	38,000	Nickel monoxide	1,600
Boron oxide	82,000	Phosphorous pentaoxide	7,600
Barium oxide	1,000	Rubidium oxide	500
Calcium oxide	3,000	Silicon oxide	260,000
Ceric oxide	2,000	Strontium oxide	100
Chromic oxide	900	Thorium dioxide	23,000
Ferric oxide	76,000	Titanium dioxide	4,300
Potassium oxide	32,000	Uranium oxide	3,000
Lithium oxide	24,000	Zinc oxide	100
Magnesium oxide	5,600	Zirconium dioxide	7,100
Manganese oxide	5,200	Others	3,900
Sodium oxide	51,000		
Neodymium oxide	900	***Total***	***630,000***

a. Sources: DIRS 103500-WVNS (n.d., WQR-1.1, Rev. 1, p. 7); DIRS 104413-Picha (1998, p. 3).
b. To convert kilograms to pounds, multiply by 2.2046.

Table A-38. Idaho National Engineering and Environmental Laboratory waste stream thermal output (watts).[a,b]

Output per waste canister	INTEC glass matrix	ANL-W ceramic matrix	ANL-W metal matrix
Average[c]	7.1	160	170
Worst case [d]	180	620	410

a. Source: DIRS 104406-Picha (1997, Attachment 1, p. 2).
b. INTEC = Idaho Nuclear Technology and Engineering Center; ANL-W = Argonne National Laboratory-West.
c. Based on average case; 2035 used as base year for Idaho Nuclear Technology and Engineering Center glass and 2000 for ANL-W matrices.
d. Based on worst case; 2020 used as base year for Idaho Nuclear Technology and Engineering Center glass and 2000 for ANL-W matrices.

Savannah River Site. The radionuclide inventories reported for the Savannah River Site high-level radioactive waste in Section A.2.3.5.2 were used to calculate projected heat generation rates for single canisters.

For the design-basis waste form, the heat generation rates 10 and 20 years after production are 465 and 302 watts per canister, respectively (DIRS 101909-Plodinec, Moore, and Marra 1993, pp. 8 and 9).

West Valley Demonstration Project. West Valley has calculated heat generation rates for a nominal West Valley canister after several different decay times (DIRS 103500-WVNS n.d., WQR-3.8, Rev. 5, 6/29/00, p. 3). In the nominal case, the ORIGEN2-computed heat generation rate was 239 watts at the calculational base time in 1988. The heat generation rate would decrease continuously from 239 watts to about 155 watts after 19 years of additional decay.

A.2.3.5.5 *Quantity of Waste Per Canister*

Table A-39 lists the estimated mass of glass per waste canister for each high-level radioactive waste stream.

Table A-39. Approximate mass of high-level radioactive waste glass per canister (kilograms).[a]

Waste stream[b]	Mass per canister	Source
Hanford	3,040	DIRS 104406-Picha (1997, Attachment 1, p. 2)
INEEL		
INTEC	1,560	DIRS 104406-Picha (1997, Attachment 1, p. 2)
ANL-W ceramic[c]	960 - 1,500	DIRS 104389-Goff (1998, Attachment, p. 5)
ANL-W metal[c]	1,500 - 4,850	DIRS 104389-Goff (1998, Attachment, p. 5)
Savannah River Site	2,000	DIRS 104403-Pearson (1998, all)
WVDP	2,000	DIRS 104406-Picha (1997, Attachment 1, p. 2)

a. To convert kilograms to pounds, multiply by 2.2046.
b. INEEL = Idaho National Engineering and Environmental Laboratory; INTEC = Idaho Nuclear technology and Engineering Center; ANL-W = Argonne National Laboratory-West; WVDP = West Valley Demonstration Project.
c. These values are estimates. ANL-W is evaluating waste package configurations compatible with existing storage and remote hot cell facilities. The geometries would be compatible with the Defense Waste Processing Facility high-level radioactive waste canister.

A.2.3.5.6 *High-Level Radioactive Waste Canister Parameters*

Hanford Site. Table A-40 lists preliminary physical parameters for a standard canister used for high-level radioactive wastes from the Hanford Site (DIRS 104406-Picha 1997, Table RL-3).

Idaho National Engineering and Environmental Laboratory. The Idaho Nuclear Technology and Engineering Center would use stainless-steel canisters identical in design to those used at the Savannah River Site in the Defense Waste Processing Facility. A similar canister would also be used to contain the ceramic and metal waste matrices resulting from the high-level radioactive waste processing at Argonne National Laboratory-West (DIRS 104406-Picha 1997, Table ID-1).

Savannah River Site. The fabrication specifications of the Defense Waste Processing Facility high-level radioactive waste canisters are described in detail in DIRS 101854-Marra, Harbour, and Plodinec (1995, all). The 3-meter (10-foot) long canisters are fabricated from four basic pieces of A240 304L austenitic stainless steel—the main cylinder, the bottom head, the top head, and a nozzle.

Table A-40. Parameters of the proposed standard canister for Hanford high-level radioactive waste disposal.[a]

Parameter	Value[b]	Comments[c]
Length	4.50 meters	1.5 meters longer than DWPF and WVDP canisters - nominal 4.5-meter length
Nominal outer diameter	0.61 meter	Same as DWPF and WVDP canisters
Material	304L stainless steel	Same as DWPF and WVDP canisters
Canister weight	720 kilograms	
Dished bottom	Yes	Same as DWPF and WVDP
Available volume	1.2 cubic meters	
Nominal percent fill	90 percent	Provides approximately same void volume as WVDP canister
Glass volume	1.1 cubic meters	

a. Source: DIRS 104406-Picha (1997, Table RL-3).
b. To convert meters to feet, multiply by 3.2808; to convert centimeters to inches, multiply by 0.3937; to convert kilograms to tons, multiply by 0.0011023; to convert cubic meters to cubic feet, multiply by 35.314.
c. DWPF = Defense Waste Processing Facility; WVDP = West Valley Demonstration Project.

West Valley Demonstration Project. The West Valley canister is designed, fabricated, and handled in accordance with the specifications in the West Valley Demonstration Project Waste Qualification Report (DIRS 103500-WVNS n.d., WQR-2.2). The West Valley canisters are also 3 meters (10 feet) long and fabricated from four principal 304L austenitic stainless-steel components.

A.2.3.5.7 *Nonstandard Packages*

Each site that would ship high-level radioactive waste to the repository has provided additional data on an estimate of nonstandard packages for possible inclusion in the candidate waste material. The mass, volume, and radioactivity of potential nonstandard packages would be dominated by failed or spent melters from the vitrification facilities. Final disposition plans for these melters are in development and vary from site to site. The EIS used the following assumptions to estimate the potential inventory.

Hanford Site. DOE could need to ship such nonstandard high-level radioactive waste packages as failed melters and failed contaminated high-level radioactive waste processing equipment to the repository. For this EIS, the estimated volume of nonstandard packages available for shipment to the repository from the Hanford Site would be equivalent to that described below for the Savannah River Site.

Idaho National Engineering and Environmental Laboratory. DOE proposes to treat and dispose of nonstandard packages under existing regulations. However, to bound the number of failed melters the Idaho National Engineering and Environmental Laboratory could ship to the repository, this EIS uses the same ratio of failed melters to the number of canisters produced as the Savannah River Site (DIRS 104401-Palmer 1997, p. 2). The Idaho National Engineering and Environmental Laboratory would produce approximately 20 percent of the number of canisters produced at the Savannah River Site, which assumes 10 failed melters. Therefore, the Idaho National Engineering and Environmental Laboratory assumes two failed melters. The volumes and other parameters would then be twice the values listed in Table A-41 for an individual melter.

Savannah River Site. Table A-41 lists the estimated parameters of nonstandard packages for repository shipment from the Savannah River Site.

West Valley Demonstration Project. The West Valley Demonstration Project anticipates that it would send only one melter to the repository at the end of the waste solidification campaign. It would be disposed of as a nonstandard package. Table A-42 lists the estimated parameters of nonstandard packages from the West Valley Demonstration Project.

Table A-41. Parameters of nonstandard packages from Savannah River Site.[a]

Parameter	Value
Volume	10 melters based on current planning to 2021
Activity	4.5 equivalent DWPF[b] canisters for each melter
Mass	1,000 metric tons[c] for 10 melters (filled melter: 100 metric tons)
Chemical composition	Glass (see Section A.2.3.5.3) Melter – Refractory brick Aluminum Stainless steel Inconel
Quantity per disposal package	1 melter per disposal package
Thermal generation	4.5 times the heat generation of a single canister for each melter

a. Source: DIRS 104402-Pearson (1997, Attachment 1, pp. 3 and 4).
b. DWPF = Defense Waste Processing Facility.
c. To convert metric tons to tons, multiply by 1.1023.

Table A-42. Parameters of nonstandard packages from West Valley Demonstration Project.[a]

Parameter	Value[b]
Volume	1 melter (24 cubic meters)
Activity	1.1 equivalent West Valley canisters
Mass	52 metric tons
Chemical composition	Melter refractories (38 metric tons) Inconel (11 metric tons) Stainless steel (1.6 metric tons) Glass (see Table A-37)
Quantity per disposal package	1 melter per package
Thermal generator	1.1 times the heat generation of a single canister (see Section A.2.3.5.4)

a. Source: DIRS 104418-Rowland (1997, all).
b. To convert cubic meters to cubic feet, multiply by 35.314; to convert metric tons to tons, multiply by 1.1023.

A.2.4 SURPLUS WEAPONS-USABLE PLUTONIUM

A.2.4.1 Background

The President has declared an amount of weapons-usable plutonium to be surplus to national security needs (DIRS 118979-DOE 1999, p. 1-1). This material includes the following:

- Plutonium in various forms (metal, oxide, etc.)
- Nuclear weapons components
- Materials that DOE could process in the future to produce purified plutonium
- Plutonium residues that DOE previously saved for future recovery of purified plutonium

These materials are currently stored at various facilities throughout the United States. DOE would draw the specific surplus weapons-usable plutonium it ultimately disposed of from the larger inventory primarily stored at these sites.

DOE could process the surplus weapons-usable plutonium as two material streams. One stream would be an immobilized plutonium ceramic form that DOE would dispose of using a can-in-canister technique with high-level radioactive waste. The second stream would be mixed uranium and plutonium oxide fuel assemblies that would be used for power production in light-water reactors and disposed of as commercial spent nuclear fuel. The Surplus Plutonium Disposition Final Environmental Impact

Statement (DIRS 118979-DOE 1999, p. 1-1) evaluates the quantity of plutonium processed in each stream. This EIS assumes that approximately one-third of the surplus weapons-usable plutonium would be immobilized and two-thirds would be made into mixed-oxide commercial nuclear fuel. The actual split could include the immobilization of up to the entire inventory of plutonium addressed in DIRS 118979-DOE (1999, p. 1-1).

A.2.4.2 Sources

DOE would produce the immobilized plutonium and/or mixed-oxide fuel at the Savannah River Site as determined in a Record of Decision for the Surplus Plutonium Disposition Final Environmental Impact Statement (65 *FR* 1608; January 11, 2000). The Department analyzed the potential environmental impacts of using mixed-oxide fuel in six commercial light-water reactors in which it proposes to irradiate the mixed-oxide fuel: both units at Catawba in South Carolina; both units at McGuire in North Carolina; and both units at North Anna Power Station in Virginia (65 *FR* 1608, January 11, 2000). Subsequently, the Department has decided to pursue irradiation of mixed-oxide fuel at only the Catawba and McGuire units.

A.2.4.3 Present Storage and Generation Status

DOE suspended planning and work activities for the immobilized plutonium program in April 2001. For planning purposes, immobilized plutonium production could start in 2012. DOE has not determined an immobilized plutonium production completion date.

The immobilization of one-third of the plutonium would produce an estimated 101 additional canisters of high-level radioactive waste, which the production location would store until shipment to the repository. The immobilization of the full considered inventory of plutonium would produce an estimated 272 additional canisters of high-level radioactive waste. This EIS assumes that the production location would be the Savannah River Site and, therefore, used the physical dimensions of the Defense Waste Processing Facility canisters to calculate these values (DIRS 118979-DOE 1999, pp. 2-26 and 2-27).

Commercial light-water reactors would use mixed-oxide fuel assemblies for power production starting as early as 2007. This fuel would replace the low-enriched uranium fuel that normally would be in the reactors. After the fuel assemblies were discharged from the reactors as spent mixed-oxide fuel, the reactor sites would store them until shipment to the repository.

A.2.4.4 Final Waste Form

The final waste form would be immobilized plutonium or spent mixed-oxide fuel. Section A.2.4.5 discusses the characteristics of these materials. The spent mixed-oxide fuel discussed here has different characteristics than the mixed-oxide fuel included in the National Spent Fuel Program (DIRS 153072-Wheatley 2000, all) and described in Section A.2.2.

A.2.4.5 Material Characteristics

A.2.4.5.1 *Mixed-Oxide Fuel*

A.2.4.5.1.1 Mass and Volume. The EIS on surplus weapons-usable plutonium disposition (DIRS 118979-DOE 1999, p. 1-9) evaluates the disposal of two-thirds of the plutonium as mixed-oxide fuel. The amount of plutonium and uranium measured in metric tons of heavy metal going to a repository would depend on the average percentage of plutonium in the fuel. The percentage of plutonium would be influenced by the fuel design. DOE has chosen pressurized-water reactors for the proposed irradiation of these assemblies. For pressurized-water reactors, the expected average plutonium percentages would be approximately 4.6 percent; however, they could range between 3.5 and 6 percent (DIRS 104422-Stevenson 1997, pp. 5 and 6). Table A-43 lists estimates and ranges for the total metric tons of heavy metal (uranium and plutonium) that would result from disposing of two-thirds of the plutonium in mixed-oxide fuel. The table also lists a corresponding estimate for the number of assemblies required, based on using the typical assemblies described in Section A.2.1.4. The ranges of metric tons of heavy metal account for the proposed range in potential plutonium percentage.

Table A-43. Estimated spent nuclear fuel quantities for disposition of two-thirds of the surplus weapons-usable plutonium in mixed-oxide fuel.[a,b]

Reactor and fuel type	Plutonium percentage	Best estimate (MTHM)	Assemblies required	Range (MTHM)
Pressurized-water reactor	4.56	700	1,500	500-900

a. Source: DIRS 104422-Stevenson (1997, pp. 5 and 6).
b. MTHM = metric tons of heavy metal; to convert metric tons to tons, multiply by 1.1023.

DOE assumed that each spent mixed-oxide assembly irradiated and disposed of would replace an energy-equivalent, low-enriched uranium assembly originally intended for the repository. The mixed-oxide assemblies would be part of the 63,000 metric tons (69,000 tons) that comprise the commercial spent nuclear fuel disposal amount in the Proposed Action (DIRS 104405-Person 1998, all). DOE also assumes that the average burnup levels for the pressurized-water reactor would be the same as that for the energy-equivalent, low-enriched uranium fuel. Table A-44 lists the assumed burnup levels and the amount of heavy metal in an assembly.

Table A-44. Assumed design parameters for typical mixed-oxide assembly.[a]

Parameter	Pressurized-water reactor
Mixed-oxide and low-enriched uranium burnup (MWd/MTHM)[b]	45,000
Mixed-oxide assembly mass (kilograms[c] of heavy metal)	450
Mixed-oxide assembly percentage of plutonium	4.56

a. Source: DIRS 104422-Stevenson (1997, p. 7).
b. MWd/MTHM = megawatt days per metric ton of heavy metal; to convert metric tons to tons, multiply by 1.1023.
c. To convert kilograms to pounds, multiply by 2.2046.

The analysis assumed that the mixed-oxide spent nuclear fuel would replace the low-enriched uranium fuel. Because of the similarities in the two fuel types, impacts to the repository would be small. Nuclear criticality, radionuclide release rates, and heat generation comparisons are evaluated in DIRS 104422-Stevenson (1997, pp. 35 to 37).

A.2.4.5.1.2 Amount and Nature of Radioactivity. Tables A-45 and A-46 list isotopic composition data for spent mixed-oxide fuel assemblies. The tables reflect SCALE data files from an Oak Ridge National Laboratory report used with computer simulation to project the characteristics of spent mixed-oxide fuel in pressurized-water reactors (DIRS 100976-Murphy 1997, Volume 3, Appendix B). The tables summarize data for two different potential fuel assemblies: a typical pressurized-water reactor, and a high-burnup pressurized-water reactor. A high burnup pressurized-water assembly would be irradiated for three cycles in comparison to the two cycles for the typical assemblies. For each of these assemblies, the tables provide radioactivity data for the common set of nuclides used in this EIS for the assumed 5-year minimum cooling time.

A.2.4.5.1.3 Chemical Composition. Tables A-47 and A-48 list the elemental distributions for the typical and high-burnup pressurized-water reactor spent mixed-oxide fuel assemblies.

A.2.4.5.1.4 Thermal Output. Table A-49 lists the decay heat from the representative mixed-oxide spent fuel assemblies at a range of times after discharge.

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Table A-45. Radionuclide activity for typical pressurized-water reactor spent mixed-oxide assembly.[a]

Radionuclide[b]	Curies per assembly	Radionuclide[b]	Curies per assembly
Hydrogen-3	2.0×10^{2}	Samarium-151	5.3×10^{2}
Carbon-14	3.4×10^{-1}	Uranium-234	4.9×10^{-2}
Cobalt-60	1.7×10^{3}	Uranium-235	1.0×10^{-3}
Nickel-59	1.1	Uranium-236	6.4×10^{-3}
Nickel-63	1.4×10^{2}	Uranium-238	1.4×10^{-1}
Krypton-85	1.9×10^{3}	Plutonium-238	1.2×10^{3}
Strontium-90	1.7×10^{4}	Plutonium-239	6.6×10^{2}
Zirconium-93	6.5×10^{-2}	Plutonium-240	8.6×10^{2}
Niobium-93m	2.8×10^{1}	Plutonium-241	2.0×10^{5}
Niobium-94	6.8×10^{-1}	Americium-241	2.2×10^{3}
Technetium-99	6.3	Americium-242/242m	3.4×10^{1}
Ruthenium-106	1.6×10^{4}	Americium-243	2.4×10^{1}
Iodine-129	2.1×10^{-2}	Curium-242	6.0×10^{1}
Cesium-134	1.4×10^{4}	Curium-243	3.2×10^{1}
Cesium-137	4.7×10^{4}	Curium-244	2.6×10^{3}

a. Source: DIRS 100976-Murphy (1997, Appendix B).
b. Half-lives are listed in Table A-11.

Table A-46. Radionuclide activity for high-burnup pressurized-water reactor spent mixed-oxide assembly.[a, b]

Radionuclide[b]	Curies per assembly	Radionuclide[b]	Curies per assembly
Hydrogen-3	2.9×10^{2}	Uranium-234	6.8×10^{-2}
Carbon-14	5.4×10^{-1}	Uranium-235	6.7×10^{-4}
Cobalt-60	2.4×10^{3}	Uranium-236	7.7×10^{-3}
Nickel-59	1.7	Uranium-238	1.5×10^{-1}
Nickel-63	2.3×10^{2}	Plutonium-238	2.7×10^{3}
Krypton-85	2.6×10^{3}	Plutonium-239	4.6×10^{2}
Strontium-90	2.4×10^{4}	Plutonium-240	8.8×10^{2}
Niobium-93m	3.9×10^{1}	Plutonium-241	2.2×10^{5}
Niobium-94	9.8×10^{-1}	Americium-241	2.5×10^{3}
Technetium-99	9.0	Americium-242/242m	4.9×10^{1}
Ruthenium-106	1.8×10^{4}	Americium-243	5.6×10^{1}
Iodine-129	3.0×10^{-2}	Curium-242	1.0×10^{2}
Cesium-134	2.5×10^{4}	Curium-243	8.5×10^{1}
Cesium-137	7.0×10^{4}	Curium-244	8.9×10^{3}
Samarium-151	5.4×10^{2}		

a. Sources: DIRS 100976-Murphy (1997, Volume 3, Appendix B).
b. Half-lives are listed in Table A-11.

A.2.4.5.1.5 Physical Parameters. Because the mixed-oxide fuel would replace low-enriched uranium fuel in existing reactors, Section A.2.1.5.5 describes the physical parameters, with the exception of uranium and plutonium content, which are listed in Table A-44.

A.2.4.5.2 *Immobilized Plutonium*

DOE has not yet determined the total quantity of plutonium for immobilization. The Department assumes that two-thirds of the considered inventory is "clean" metal suitable for use in mixed-oxide fuel, and that it could dispose of this material by burning it in reactors (DIRS 118979-DOE 1999, p. 1-1). The remaining surplus plutonium would require considerable additional chemical processing to make it suitable for reactor use. This EIS evaluates two cases, one in which DOE immobilizes only the "impure" materials (base case) and a second in which it immobilizes the entire considered surplus inventory. The base case is evaluated for the Proposed Action because it is DOE's preferred alternative (DIRS 118979-

Table A-47. Elemental distribution of typical burn-up pressurized-water reactor spent mixed-oxide assembly.[a]

Element	Grams per assembly[b]	Percent[c]	Element	Grams per assembly	Percent
Americium	770	0.12	Palladium	1,200	0.19
Barium	750	0.12	Phosphorus	140	0.02
Carbon	67	0.01	Plutonium	17,000	2.59
Cerium	1,100	0.16	Praseodymium	500	0.08
Cesium	1,500	0.23	Rhodium	360	0.05
Chromium	2,300	0.36	Rubidium	91	0.01
Europium	90	0.01	Ruthenium	1,300	0.20
Iodine	150	0.02	Samarium	440	0.07
Iron	4,600	0.71	Silicon	66	0.01
Krypton	100	0.02	Strontium	210	0.03
Lanthanum	540	0.08	Technetium	370	0.06
Manganese	110	0.02	Tellurium	260	0.04
Molybdenum	1,700	0.27	Tin	1900	0.28
Neodymium	1,700	0.26	Uranium	428,000	65.92
Neptunium	72	0.01	Xenon	2500	0.38
Nickel	4,400	0.68	Yttrium	110	0.02
Niobium	330	0.05	Zirconium	111,000	17.10
Oxygen	62,000	9.56	***Totals***	***648,000***	***99.73***

a. Source: DIRS 104399-Murphy (1998, all).
b. To convert grams to ounces, multiply by 0.035274.
c. Table includes only elements that constitute at least 0.01 percent of the total; therefore, total is slightly less than 100 percent.

Table A-48. Elemental distribution of high burn-up pressurized-water reactor spent mixed-oxide assembly.[a]

Element	Grams per assembly[b]	Percent[c]	Element	Grams per assembly	Percent
Americium	1,000	0.16	Palladium	2,000	0.30
Barium	1,200	0.18	Phosphorus	140	0.02
Carbon	70	0.01	Plutonium	14,000	2.22
Cerium	1,600	0.24	Praseodymium	750	0.11
Cesium	2,100	0.33	Rhodium	460	0.07
Chromium	2,300	0.36	Rubidium	140	0.02
Europium	140	0.02	Ruthenium	2,000	0.31
Iodine	220	0.03	Samarium	630	0.10
Iron	4,600	0.71	Silicon	66	0.01
Krypton	150	0.02	Strontium	300	0.05
Lanthanum	810	0.12	Technetium	520	0.08
Manganese	100	0.02	Tellurium	390	0.06
Molybdenum	2,500	0.39	Tin	1,900	0.29
Neodymium	2,500	0.39	Uranium	421,000	64.84
Neptunium	93	0.01	Xenon	3,700	0.57
Nickel	4,400	0.68	Yttrium	170	0.03
Niobium	330	0.05	Zirconium	111,000	17.10
Oxygen	62,000	9.56	***Totals***	***646,000***	***99.46***

a. Source: DIRS 104399-Murphy (1998, all).
b. To convert grams to ounces, multiply by 0.035274.
c. Table includes only elements that constitute at least 0.01 percent of the total; therefore, total is slightly less than 100 percent.

DOE 1999, p. 1-1). The EIS evaluates the second case for potential cumulative impacts (Modules 1 and 2) because it would conservatively predict the largest number of required high-level radioactive waste canisters.

Table A-49. Mixed-oxide spent nuclear fuel thermal profile (watts per assembly).[a]

Years	Typical PWR[b]	High-burnup PWR
1	6,100	8,000
5	1,000	1,600
10	670	1,100
15	610	970
30	540	780
100	370	430
300	240	260
1,000	110	110
3,000	42	38
10,000	25	22
30,000	10	7.9
100,000	1.5	1.3
250,000	0.5	0.6

a. Source: DIRS 100976-Murphy (1997, Volume 3, Appendix B).
b. PWR = pressurized-water reactor.

A.2.4.5.2.1 Mass and Volume. In DOE's preferred disposition alternative, immobilized plutonium would arrive at the repository in canisters of vitrified high-level radioactive waste that would be externally identical to standard canisters from the Defense Waste Processing Facility at the Savannah River Site. Smaller cans containing immobilized plutonium in ceramic disks would be embedded in each canister of high-level radioactive waste glass. This is the *can-in-canister* concept. Because the design of the can-in-canister is not final, DOE has not determined final waste loadings per canister, volume displaced by the cans, or other specifications. DOE estimates that each canister would contain 28 cans, but has not yet finalized the actual number. One of the limitations on the number of cans is determined by the ability to ensure that the high-level radioactive waste glass would fill completely around the cans; increasing the volume that the cans would occupy in a canister could increase the difficulty of achieving this.

Marra, Harbour, and Plodinec (DIRS 101854-1995, p. 2) describes the volume of a high-level radioactive waste canister. Each canister has a design capacity of 2,000 kilograms (4,400 pounds) of high-level radioactive waste glass. A nominal glass density of 2.7 grams per cubic centimeter (0.10 pound per cubic inch) yields a design glass volume of 620 liters (22 cubic feet). The 28 cans containing plutonium would displace 68 liters (2.4 cubic feet), or about 11 percent of the available volume. The rack holding the cans would displace about an additional 1 percent of the available volume, yielding a total displacement of about 12 percent.

Table A-50 lists the number of high-level radioactive waste canisters required to dispose of immobilized surplus plutonium using the loading and volumetric assumptions given above for both the base and full inventory cases. It also lists the number of additional canisters DOE would have to produce (in addition to those the high-level radioactive waste producer would already have produced) due to the displacement of high-level radioactive waste glass by the plutonium-containing canisters. The total number of required canisters would be a function of both the number of cans in each canister and the plutonium loading of the immobilization form. The number of additional canisters would depend only on the plutonium loading of the immobilization form.

A.2.4.5.2.2 Amount and Nature of Radioactivity. Assuming the current 10.5-percent plutonium loading in the ceramic, the expected isotopic composition of the various materials in the feedstream for ceramic production, and the nominal quantity of ceramic in each canister, Stevenson (DIRS 104422-1997, p. 49) calculated the activity of the immobilized material in each high-level radioactive waste canister.

Table A-50. Number of canisters required for immobilized plutonium disposition.[a,b]

Canisters	Base case	Full inventory case
Containing plutonium	670	1,820
In excess of those required for DWPF[c] (12% of total canisters)	101	272
Additional[d]	1.7%	4.5%

a. Source: DIRS 118979-DOE (1999, p. 2-29).
b. Assumes displacement of 12 percent of the high-level radioactive waste glass by plutonium cans and rack.
c. DWPF = Defense Waste Processing Facility.
d. As percentage of total planned DWPF canisters (about 6,000).

The figures do not include the radioactivity of the vitrified high-level radioactive waste that would surround the cans of immobilized plutonium. Calculation of the total radioactivity of a canister requires the subtraction of approximately 12 percent from the radioactivity of a full high-level radioactive waste canister to account for the displacement of the immobilized plutonium and its rack. Those reduced numbers, added to the appropriate figures in Table A-51, produce the total activity of a plutonium-containing high-level radioactive waste canister.

Table A-51. Average total radioactivity of immobilized plutonium ceramic in a single canister in 2010 (curies).[a,b]

Radionuclide[c]	Base case	Full inventory
Plutonium-238	120	60
Plutonium-239	1,600	1,700
Plutonium-240	550	430
Plutonium-241	4,700	2,800
Plutonium-242	0.098	0.046
Americium-241	720	430
Uranium-234	< 0.000015[d]	< 0.000005
Uranium-235	0.0024	< 0.0011
Uranium-238	0.019	0.019
Thorium-232	< 0.00003	< 0.00003
Totals	***7,700***	***5,400***

a. Source: DIRS 104422-Stevenson (1997, p. 49).
b. Assumes 10.5 percent of plutonium by weight in ceramic form and 1:2 molar ratio of plutonium to uranium. These values account only for the radioactivity in the immobilized form; they do not include that in the surrounding high-level radioactive waste glass.
c. Half-lives are listed in Table A-11.
d. < = less than.

Values for the base case and the full inventory case are different because the plutonium in the base case contains more transuranic radionuclides, other than plutonium-239, than does the remainder of the plutonium. Thus, the “other” transuranic radionuclides are diluted in the full inventory case. From a thermal output and radiological impact standpoint, the base case is a more severe condition and, therefore, DOE has used it for the Proposed Action analysis.

Section A.2.3.5.2 contains information on the radioactivity contained in a standard Defense Waste Processing Facility high-level radioactive waste canister.

A.2.4.5.2.3 Chemical Composition. The current design for a ceramic immobilization form is a multiphase titanate ceramic, with a target bulk composition listed in Table A-52. The neutron absorbers, hafnium and gadolinium, are each present at a 1-to-1 atomic ratio to plutonium, and the atomic ratio of uranium to plutonium is approximately 2-to-1. For the base case, the presence of impurities in some categories of surplus weapons-usable plutonium would result in the presence of a few weight percent of other nonradioactive oxides in some of the actual ceramic; Table A-52 does not list these impurities (DIRS 104422-Stevenson 1997, p. 51).

Table A-52. Chemical composition of baseline ceramic immobilization form.[a]

Oxide	Approximate percent by weight
Titanium oxide	36
Hafnium oxide	10
Calcium oxide	10
Gadolinium oxide	8
Plutonium oxide	12
Uranium oxide	24

a. Source: DIRS 104422-Stevenson (1997, p. 51).

The ceramic phase assemblage is mostly Hf-pyrochlore [(CaGd)(Gd,Pu,U,Hf)Ti_2O_7], with subsidiary Hf-zirconolite [(CaGd)(Gd,Pu,U,Hf)Ti_2O_7)], and minor amounts of brannerite [(U,Pu,Gd)Ti_2O_6] and rutile [(Ti,Hf)O_2]. Pyrochlore and zirconolite differ in their crystalline structures. The presence of silicon as an impurity in the plutonium could lead to the formation of a minor amount of a silicate glass phase in the ceramic. This phase could contain a trace amount of the immobilized plutonium. Some residual plutonium oxide (less than 0.5 percent of the total quantity of plutonium) could also be present. The residual plutonium oxide contains uranium with smaller amounts of gadolinium and hafnium as a result of partial reaction with the other constituents of the ceramic (DIRS 104422-Stevenson 1997, p. 51). Section A.2.3.5.3 describes the chemical composition of the high-level radioactive waste glass surrounding the plutonium-containing cans.

A.2.4.5.2.4 Thermal Output. DIRS 104422-Stevenson (1997, p. 49) has presented the heat generation of the immobilized ceramic. These figures represent only the heat from the ceramic; they do not account for the heat from the surrounding high-level radioactive waste glass. The total heat from a Defense Waste Processing Facility canister containing high-level radioactive waste and immobilized plutonium would be the value listed in Table A-53 combined with 88 percent of the value listed in Section A.2.3.5.4 for the heat from a Defense Waste Processing Facility canister.

Table A-53. Thermal generation from immobilized plutonium ceramic in a single canister in 2010 (watts per canister).[a]

Case	Thermal production
Base case	8.6
Full inventory case	7.0

a. Source: DIRS 104422-Stevenson (1997, p. 49).
b. To convert metric tons to tons, multiply by 1.1023.

A.2.5 COMMERCIAL GREATER-THAN-CLASS-C LOW-LEVEL WASTE

A.2.5.1 Background

Title 10 of the Code of Federal Regulations, Part 61 (10 CFR Part 61), establishes disposal requirements for three classes of waste—A, B, and C—suitable for near-surface disposal. Class C has the highest level of radioactivity and therefore the most rigorous disposal specifications. Wastes with concentrations above Class C limits (listed in 10 CFR 61.55 Tables 1 and 2 for long and short half-life radionuclides, respectively) are called Greater-Than-Class-C low-level waste, and are not generally suitable for near-surface disposal (DIRS 101798-DOE 1994, all).

Commercial nuclear powerplants, research reactors, radioisotope manufacturers, and other manufacturing and research institutions generate waste that exceeds the Nuclear Regulatory Commission Class C shallow-land-burial disposal limits. Public Law 99-240 assigns the Federal Government, specifically DOE, the responsibility for disposing of this Greater-Than-Class-C waste. DOE could use a number of techniques for the disposal of these wastes, including engineered near-surface disposal, deep borehole disposal, intermediate-depth burial, and disposal in a deep geologic repository (DIRS 101798-DOE 1994, all).

The activities of nuclear electric utilities and other radioactive waste generators to date have produced relatively small quantities of Greater-Than-Class-C waste. As the utilities take their reactors out of service and decommission them, they could generate more waste of this type (DIRS 101798-DOE 1994, all).

Greater-Than-Class-C waste could include the following materials:

- Nuclear powerplant operating wastes
- Nuclear powerplant decommissioning wastes
- Sealed radioisotope sources that exceed Class C limits for waste classification
- DOE-held Greater-Than-Class-C waste (addressed in Section A.2.6)
- Greater-Than-Class-C waste from other generators

This section describes the quantities and characteristics of these waste types.

A.2.5.2 Sources

Sources or categories of Greater-Than-Class-C waste include:

- DOE facilities (addressed in Section A.2.6)
- Nuclear utilities
- Sealed sources
- Other generators

Nuclear utility waste includes activated metals and process wastes from commercial nuclear powerplants. Sealed sources are radioactive materials in small metallic capsules used in measurement and calibration devices. Other generator wastes consist of sludge, activated metals, and other wastes from radionuclide manufacturers, commercial research, sealed-source manufacturers, and similar operations. The decommissioning of light-water reactors probably will generate additional Greater-Than-Class-C waste. Some internal reactor components will exceed Class C disposal limits.

A.2.5.3 Present Status

Nuclear utilities store their Greater-Than-Class-C waste at the generator site, where it will remain until a disposal option becomes available.

Sealed sources are held by a Nuclear Regulatory Commission or Agreement State licensee. Current DOE sealed-source management plans call for the licensees to store their sealed-source wastes until a disposal option becomes available. If storage by a licensee became physically or financially impossible and a threat to public health and safety, the Nuclear Regulatory Commission would determine if the source was a candidate for DOE storage. At that time, the Commission could request that DOE accept the source for storage, reuse, or recycling. The inventory projections do not include such a transfer of material.

In 1993, there were 13 identified "other generators" of Greater-Than-Class-C waste (DIRS 101798-DOE 1994, Appendix D), which were categorized into seven business types:

- Carbon-14 user
- Industrial research and development
- Irradiation laboratory
- Fuel fabricator
- University reactor
- Sealed-source manufacturer
- Nonmedical academic institution

These generators store their wastes at their sites and will continue to do so until a disposal site becomes operational.

A.2.5.4 Final Waste Form

The final disposition method for Greater-Than-Class-C waste is not known. If DOE was to place such waste in a repository, it is assumed that it would be placed in a disposal canister before shipment. The EIS assumes the use of a canister similar to the naval canister, which is described in Section A.2.2.5.6, for all shipments by rail and a package similar to the high-level radioactive waste canisters for all shipments by truck.

A.2.5.5 Waste Characteristics

Table A-54 lists existing and projected volumes for the three Greater-Than-Class-C waste generator sources. DOE conservatively projects the volume of nuclear utility wastes to 2055 because that date would include the majority of this waste from the decontamination and decommissioning of commercial nuclear reactors. The projected volumes conservatively reflect the highest potential volume and activity based on inventories, surveys, and industry production rates. DOE projects the other two generator sources (sealed sources and other generators) to 2035 (DIRS 101798-DOE 1994, all).

Table A-54. Greater-Than-Class-C waste volume by generator source (cubic meters).[a,b]

Source	1993 volume	Projected volume
Nuclear electric utility	26	1,300
Sealed sources	39	240
Other generators	74	470
Totals	***139***	***2,010***

a. Source: DIRS 101798-DOE (1994, all).
b. To convert cubic meters to cubic feet, multiply by 35.314.

The data concerning the volumes and projections are from Greater-Than-Class-C Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics (DIRS 101798-DOE 1994, Appendix A-1), which provides detailed radioactivity reports for such waste currently stored at nuclear utilities. Table A-55 summarizes the radioactivity data for the primary radionuclides in the waste, projected to 2055.

Table A-55. Commercial Greater-Than-Class-C waste radioactivity (curies) by nuclide (projected to 2055).[a]

Nuclide[b]	Radioactivity
Carbon-14	6.8×10^{4}
Cobalt-60	3.3×10^{7}
Iron-55	1.8×10^{7}
Hydrogen-3	1.2×10^{4}
Manganese-54	3.2×10^{4}
Niobium-94	9.8×10^{2}
Nickel-59	2.5×10^{5}
Nickel-63	3.7×10^{7}
Transuranics	2.0×10^{3}
Total	***8.8×10^{7}***

a. Source: DIRS 101798-DOE (1994, Appendix A-1).
b. Half-lives are listed in Table A-11.

Appendix B of DIRS 101798-DOE (1994) provides detailed radioactivity reports for the sealed sources, which could be candidate wastes for the repository. Table A-56 summarizes the radioactivity data for the radionuclides in these sources, projected to 2035.

Table A-56. Sealed-source Greater-Than-Class-C waste radioactivity (curies) by nuclide (projected to 2035).[a]

Nuclide[b]	Radioactivity
Americium-241	8.0×10^{4}
Curium-244	1.6×10^{2}
Cesium-137	4.0×10^{7}
Plutonium-238	1.6×10^{4}
Plutonium-239	1.1×10^{5}
Plutonium-241	2.8×10^{1}
Technetium-99	5.8×10^{3}
Uranium-238	5.7×10^{1}
Total	***4.2×10^{7}***

a. Source: DIRS 101798-DOE (1994, Appendix A-1).
b. Half-lives are listed in Table A-11.

DIRS 101798-DOE (1994, Section 5) also identifies the 13 other generators and the current and projected volumes and total radioactivity of Greater-Than-Class-C waste held by each. It does not provide specific radionuclide activity by nuclide. DOE used the data to derive a distribution, by user business type, of the specific nuclides that comprise the total radioactivity. Table A-57 lists this distributed radioactivity for other generators.

A detailed chemical composition by weight percentage for current Greater-Than-Class-C waste is not available. However, Table A-58 lists the typical composition of such wastes by generator.

The heat generation rates or thermal profiles for this waste type are not included in the source documentation. However, the contribution to the total thermal load at the repository from the Greater-Than-Class-C radioactive waste would be very small in comparison to commercial spent nuclear fuel or high-level radioactive waste.

Table A-57. Other generator Greater-Than-Class-C waste radioactivity (in curies) by nuclide (projected to 2035).[a]

Nuclide[b]	Radioactivity
Carbon-14	7.7×10^{3}
Transuranic	2.2×10^{3}
Cobalt-60	1.5×10^{2}
Nickel-63	1.5×10^{2}
Americium-241	2.4×10^{3}
Cesium-137	6.6×10^{1}
Technetium-99	5.1×10^{-2}
Total[c]	$\boldsymbol{1.3\times10^{4}}$

a. Source: Derived from DIRS 101798-DOE (1994, Appendix D).
b. Half-lives are listed in Table A-11.
c. Total differs from sum of values due to rounding.

Table A-58. Typical chemical composition of Greater-Than-Class-C wastes.[a]

Source	Typical composition
Nuclear electric utility	Stainless steel-304, and zirconium alloys
Sealed sources	Stainless steel-304 (source material has very small mass contribution)
Other generators	Various materials

a. Source: DIRS 101798-DOE (1994, all).

A.2.6 SPECIAL-PERFORMANCE-ASSESSMENT-REQUIRED LOW-LEVEL WASTE

A.2.6.1 Background

DOE production reactors, research reactors, reprocessing facilities, and research and development activities generate wastes that exceed the Nuclear Regulatory Commission Class C shallow-land-burial disposal limits. The Department is responsible for the safe disposal of such waste, and could use a number of techniques such as engineered near-surface disposal, deep borehole disposal, intermediate-depth burial, or disposal in a deep geologic repository. These wastes have been designated as Special-Performance-Assessment Required wastes.

DOE Special-Performance-Assessment-Required waste could include the following materials:

- Production reactor operating wastes
- Production and research reactor decommissioning wastes
- Non-fuel-bearing components of naval reactors
- Sealed radioisotope sources that exceed Class C limits for waste classification
- DOE isotope production-related wastes
- Research reactor fuel assembly hardware

A.2.6.2 Sources

DOE has identified Special-Performance-Assessment-Required waste inventories at several locations. Table A-59 lists the generators and amounts of these wastes. These amounts include current and projected inventories. These inventories are subject to revision as DOE develops its site material management programs and facility decommissioning plans.

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Table A-59. Estimated Special-Performance-Assessment-Required low-level waste volume and mass by generator source.[a]

Source[b]	Volume (cubic meters)[c]	Mass (kilograms)[d]
Hanford	20	360,000
INEEL[e]	20	280,000
ORNL	2,900	4,700,000
WVDP	550	5,200,000
ANL-E	1	230
Naval Reactors Facility at INEEL	500	2,500,000
Totals (rounded)	***3,990***	***13,000,000***

a. Source: DIRS 104411-Picha (1998, all).
b. INEEL = Idaho National Engineering and Environmental Laboratory (including Argonne National Laboratory-West); ORNL = Oak Ridge National Laboratory; WVDP = West Valley Demonstration Project; ANL-E = Argonne National Laboratory-East.
c. To convert cubic meters to cubic yards, multiply by 1.3079.
d. To convert kilograms to pounds, multiply by 2.2046.
e. Includes Argonne National Laboratory-West.

A.2.6.3 Present Status

DOE stores its Special-Performance-Assessment-Required waste at the generator sites listed in Table A-59. Tables A-60 through A-63 list the waste inventories at the individual sites. For radionuclides, these tables include only the reported isotopes with inventories greater than 1×10^{-5} curies. Table A-64 lists the chemical composition of this material at each site.

Table A-60. Hanford Special-Performance-Assessment-Required low-level waste radioactivity by nuclide (curies).[a]

Nuclide[b]	Radioactivity
Cesium-137	6.0×10^{4}
Strontium-90	6.0×10^{4}

a. Source: DIRS 104411-Picha (1998, all).
b. Half-lives are listed in Table A-11.

Table A-61. Idaho National Engineering and Environmental Laboratory (including Argonne National Laboratory-West) Special-Performance-Assessment-Required low-level waste radioactivity by nuclide (curies).[a]

Nuclide[b]	Radioactivity
Hydrogen-3	5.9×10^{6}
Carbon-14	8.3×10^{2}
Cobalt-60	1.1×10^{6}
Nickel-59	9.0×10^{1}
Nickel-63	1.3×10^{4}
Strontium-90	7.4×10^{3}
Niobium-94	1.4×10^{2}
Technetium-99	3.3
Cesium-137	3.1×10^{1}
Radium-226	3.0×10^{1}
Plutonium-239	2.0×10^{1}
Americium-241	2.4×10^{2}

a. Source: DIRS 104411-Picha (1998, all).
b. Half-lives are listed in Table A-11.

Table A-62. Oak Ridge National Laboratory Special-Performance-Assessment-Required low-level waste radioactivity by nuclide (curies).[a]

Nuclide[b]	Radioactivity
Hydrogen-3	1.9×10^{6}
Carbon-14	1.0×10^{1}
Cobalt-60	1.9×10^{6}
Nickel-59	7.6×10^{3}
Nickel-63	7.5×10^{5}
Strontium-90	8.3×10^{7}
Niobium-94	1.0×10^{4}
Technetium-99	8.0×10^{-1}
Iodine-129	7.5×10^{-5}
Cesium-137	1.7×10^{-4}

a. Source: DIRS 104411-Picha (1998, all).
b. Half-lives are listed in Table A-11.

Table A-63. Radioactivity of naval Special-Performance-Assessment-Required waste (curies per package).[a]

Radionuclide[b]	Short canister	Long canister	Radionuclide	Short canister	Long canister
Americium-241	5.4×10^{-2}	6.0×10^{-2}	Nickel-59	2.2×10^{2}	2.5×10^{2}
Americium-242m	5.8×10^{-4}	6.5×10^{-4}	Nickel-63	2.7×10^{4}	3.0×10^{4}
Americium-243	5.8×10^{-4}	6.5×10^{-4}	Plutonium-239	2.1×10^{-2}	2.4×10^{-2}
Carbon-14	3.2	3.6	Plutonium-240	5.4×10^{-3}	6.0×10^{-3}
Chlorine-36	5.3×10^{-2}	6.0×10^{-2}	Plutonium-241	4.1	4.6
Curium-242	1.4×10^{-3}	1.5×10^{-3}	Plutonium-242	4.5×10^{-5}	5.1×10^{-5}
Curium-243	6.6×10^{-4}	7.4×10^{-4}	Ruthenium-106	2.1×10^{-1}	2.3×10^{-1}
Curium-244	7.0×10^{-2}	7.9×10^{-2}	Selenium-79	1.2×10^{-5}	1.3×10^{-5}
Curium-245	1.3×10^{-5}	1.5×10^{-5}	Samarium-151	1.7×10^{-2}	1.9×10^{-2}
Cesium-134	1.6	1.8	Tin-126	1.2×10^{-5}	1.3×10^{-5}
Cesium-135	1.1×10^{-5}	1.2×10^{-5}	Strontium-90	4.2×10^{-1}	4.7×10^{-1}
Cesium-137	1.1	1.3	Technetium-99	5.3×10^{-4}	6.0×10^{-4}
Hydrogen-3	1.5	1.7	Uranium-232	1.2×10^{-4}	1.4×10^{-4}
Krypton-85	4.9×10^{-2}	5.6×10^{-2}	Uranium-233	7.8×10^{-5}	8.8×10^{-5}
Niobium-93m	3.6×10^{-1}	4.1×10^{-1}	Zirconium-93	3.8×10^{-1}	4.3×10^{-1}
Niobium-94	5.9×10^{-1}	6.7×10^{-1}			

a. Source: DIRS 124679-Beckett (1998, Attachment 1).
b. Half-lives are listed in Table A-11.

Table A-64. Typical chemical composition of Special-Performance-Assessment-Required low-level waste.[a]

Source[b]	Composition
Hanford	Vitrified fission products in glass waste form; hot cell waste
INEEL	Activated metal
ORNL	Activated metal; isotope production waste; hot cell waste
WVDP	Activated metal; vitrified transuranic waste
Naval Reactors Facility at INEEL	Activated metal (zirconium alloy, Inconel, stainless steel)
Other generators	Stainless-steel sealed sources

a. Source: DIRS 104411-Picha (1998, all).
b. INEEL = Idaho National Engineering and Environmental Laboratory; ORNL = Oak Ridge National Laboratory; WVDP = West Valley Demonstration Project.

A.2.6.4 Final Waste Form

The final disposal method for DOE Special-Performance-Assessment-Required waste is not known. If the Department disposed of such waste in a repository, it is assumed that the material would be placed in a disposable package before shipment to the repository. The EIS assumes the use of a disposable canister similar to those used for naval fuels for all rail shipments and packages similar to a high-level radioactive waste canister for all truck shipments.

A.2.6.5 Waste Characteristics

The low-level waste from West Valley consists of material in the Head End Cells (5 cubic meters [177 cubic feet]) and remote-handled and contact-handled transuranic waste (545 cubic meters [19,000 cubic feet]). The estimated radioactivity of the material in the Head End Cells is 6,750 curies, while the activity of the remote-handled and contact-handled transuranic waste is not available at present (DIRS 104411-Picha 1998, all). The naval Special-Performance-Assessment-Required waste consists primarily of zirconium alloys, Inconel, and stainless steel (DIRS 124679-Beckett 1998, all); Table A-63 lists the specific radioactivity of the projected material 5 years after discharge.

The specific activity associated with the radium sources at Argonne National Laboratory-East has not been determined. However, in comparison to the other Special-Performance-Assessment-Required waste included in this section, its impact would be small.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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Appendix B

Federal Register **Notices**

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DEPARTMENT OF ENERGY

Preparation of an Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

AGENCY: Department of Energy.

ACTION: Notice of intent.

SUMMARY: The U.S. Department of Energy (DOE) announces its intent to prepare an environmental impact statement (EIS) for a geologic repository at Yucca Mountain, Nye County, Nevada, for the disposal of spent nuclear fuel and high-level radioactive waste, in accordance with the Nuclear Waste Policy Act of 1982, as amended (NWPA) (42 U.S.C. § 10101 *et seq.*), the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. § 4321 *et seq.*), the Council on Environmental Quality regulations that implement the procedural provisions of NEPA (40 CFR Parts 1500–1508), and the DOE procedures for implementing NEPA (10 CFR Part 1021). DOE invites Federal, State, and local agencies, Native American tribal organizations, and other interested parties to participate in determining the scope and content of the EIS.

The NWPA directs DOE to evaluate the suitability of the Yucca Mountain site in southern Nevada as a potential site for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. If the Secretary of Energy determines that the Yucca Mountain site is suitable, the Secretary may then recommend that the President approve the site for development of a repository. Under the NWPA, any such recommendation shall be considered a major Federal action and must be accompanied by a final environmental impact statement. Accordingly, DOE is preparing this EIS in conjunction with any potential DOE recommendation regarding the development of a repository at Yucca Mountain.

The NWPA provides that the environmental impact statement need not consider the need for a repository, the alternatives to geologic disposal, or alternative sites to the Yucca Mountain site. Therefore, this environmental impact statement will evaluate a proposal to construct, operate, and eventually close a repository at Yucca Mountain. The EIS will evaluate reasonable alternatives for implementing such a proposal in accordance with the NWPA.

The NWPA also provides that the Nuclear Regulatory Commission shall, to the extent practicable, adopt DOE's EIS in connection with any subsequent construction authorization and license that the Commission issues to DOE for a repository. The EIS process is scheduled to be completed in September 2000 and is separate from the licensing process that would be initiated by any submission of a license application by DOE to the Commission in June 2001.

The EIS will be prepared over a five-year period in conjunction with DOE's separate but parallel site suitability evaluation and potential license application. DOE is beginning the EIS process early to ensure that the appropriate data gathering and tests are performed to adequately assess potential environmental impacts, and to allow the public sufficient time to consider this complex program and to provide input.

DATES: DOE invites and encourages comments and suggestions on the scope of the EIS to ensure that all relevant environmental issues and reasonable alternatives are addressed. Public scoping meetings are discussed below in the **SUPPLEMENTARY INFORMATION** section. DOE will carefully consider all comments and suggestions received during the 120-day public scoping period that ends on December 5, 1995. Comments and suggestions received after the close of the public scoping period will be considered to the extent practicable.

ADDRESSES: Written comments on the scope of this EIS, requests to pre-register to speak at any of the public scoping meetings, questions concerning the proposed action and EIS, or requests for additional information on the EIS, should be directed to: Wendy R. Dixon, EIS Project Manager, Yucca Mountain Site Characterization Office, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, 101 Convention Center Drive Suite P–110, MS 010, Las Vegas, NV 89109, Telephone: 1–800–967–3477, Facsimile: 1–800–967–0739.

FOR FURTHER INFORMATION CONTACT: For more information about this EIS, please contact Wendy R. Dixon at the address, above. For information on DOE's NEPA process, please contact: Carol M. Borgstrom, Director, Office of NEPA Policy and Assistance (EH–42), U.S. Department of Energy, 1000 Independence Avenue, S.W., Washington, D.C. 20585, Telephone: 1–202–586–4600 or leave a message at 1–800–472–2756.

SUPPLEMENTARY INFORMATION:

Public Participation

All interested persons, including Federal agencies, Native American tribal organizations, State and local government agencies, public interest groups, transportation interests, industry and utility organizations, regulators, and the general public are encouraged to take part in the EIS scoping process. Because of the anticipated public interest and national scope of the program, DOE will provide several methods for people to express their views and provide comments, request additional information and copies of the EIS, or pre-register to speak at the scoping meetings. Comments submitted by any of these means will become part of the official record for scoping.

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Written Comments and Toll-Free Facsimile Number

Written comments and requests may be mailed or sent by facsimile to Wendy R. Dixon at the address or toll-free facsimile number listed above

Toll-Free Telephone Line

All interested parties are invited to record their comments or request information on the scope of the EIS by calling a toll-free telephone number, 1–800–967–3477. Throughout the public scoping period, this number will be staffed between the hours of 9 a.m. to 9 p.m. Eastern Standard Time, Monday through Friday. During other hours, calls will be forwarded to an answering machine.

Electronic Mail

Comments and information requests may be submitted by electronic mail to the following Internet electronic mail address: ymp—eisr@notes.ymp.gov.

Internet

The public may access the Notice of Intent, request information, and provide comments via the World Wide Web at the following Uniform Resource Locator address: http://www.ymp.gov, under the listing *Environmental Impact Statement (EIS)* on the Yucca Mountain Project Home Page. When available, the EIS and other selected technical documents may also be accessed at this Uniform Resource Locator address.

Scoping Meetings

DOE will hold 15 public scoping meetings in cities throughout the United States to provide and discuss information and to receive comments on the scope of this EIS. Table 1 at the end of this Notice lists the specific locations, dates, and times for each scoping meeting. Persons wishing to speak at any of these meetings can pre-register up to two days before the meeting by: (1) Calling the toll-free telephone number 1–800–967–3477, (2) writing to Wendy R. Dixon at the address listed above, or (3) sending their request to pre-register by facsimile or electronic mail, as identified above.

Persons wishing to speak who have not registered in advance can register at each meeting. These "walk-in registrants" will be accommodated to the extent practicable, following those persons who have pre-registered. Only one spokesperson per organization, group, or agency may present comments on its behalf. Oral statements will be limited to ten minutes; however, written comments can be of any length and submitted any time during the scoping period.

Each of the 15 public scoping meetings will have either a morning or afternoon session, and an evening session. Morning sessions will begin at 8:30 a.m. and end at 12:30 p.m., and afternoon sessions will begin at 12:00 p.m. and end at 4:00 p.m. Evening sessions will begin at 6:00 p.m. and end about 10:00 p.m. If additional time is required in order to accommodate all speakers wishing to present oral comments, the meeting facilitator will consult with the audience and DOE staff and determine whether to continue the meeting past the scheduled ending time. A court reporter will record all portions of the scoping meetings, and transcripts will be prepared and made a part of the official record of the scoping process.

Each session will have an introductory presentation, a question and answer period, and a public comment segment. A facilitator will begin the introductory presentation of each session by explaining the scoping meeting format. DOE staff will provide a brief description (lasting approximately 30–45 minutes) of the repository program, the EIS, and the scoping process. The question and answer period (lasting approximately 45 minutes) will provide members of the public an opportunity to ask questions and discuss various aspects of the repository and to obtain additional information that may be useful in formulating opinions and comments. Each member of the public will be allowed five minutes to ask questions. The meeting facilitator may allow extra time for additional questions depending on the number of people present who have indicated their desire to participate during the question and answer period. The meeting facilitator will begin the public comment portion of the scoping meeting after the question and answer period. At this time, members of the public will provide their comments on the scope of the EIS.

Each public scoping meeting also will have a separate information room containing exhibits and informational handouts about the repository program and the EIS. DOE and contractor staff will be available throughout the day to answer questions in an informal setting. A table with blank comment cards will also be available for people to privately prepare and submit written comments on the scope of the EIS. These comment cards will be included in the formal record of each scoping meeting.

Subsequent Document Preparation

Results of scoping, including the transcripts from the question and answer periods and public comment segments, and all other oral and written comments received by DOE, will be summarized in the EIS Implementation Plan. This Plan will guide the preparation of the EIS, and will describe the planned scope and content of the EIS, record the results of the scoping process, and contain EIS activity schedules. As a "living document," the Implementation Plan may be amended as needed to incorporate changes in schedules, alternatives, or EIS content.

The Implementation Plan will be available to the public for information purposes as soon as possible after the close of the public scoping process, and before issuing the Draft EIS. The Implementation Plan and the transcripts from the public scoping meetings will be available for inspection at major DOE facilities and public reading rooms in Nevada and across the country, as identified at the end of this Notice. Copies of the Implementation Plan, as well as the Draft and Final EIS and related comments, will be provided to anyone requesting copies of these documents.

Availability of the Draft EIS for public review, and the locations and times of public hearings on the Draft EIS, will be announced in the **Federal Register** and through local media (approximately in the Fall of 1998). After considering all public comments received on the Draft EIS, DOE will prepare and issue a Final EIS, followed thereafter by a Record of Decision (approximately in the Fall of 2000).

Background

Spent nuclear fuel [1] has been and is being generated and stored in the United States as part of commercial power generation. The accumulation of spent nuclear fuel from commercial power reactor operations in the United States probably will continue for several decades. There are 109 operating commercial facilities at 75 sites in 34 States where spent nuclear fuel is stored. By the year 2035, total spent nuclear fuel from power reactors will amount to about 85,000 metric tons of heavy metal (i.e., metric tons of heavy metal, typically uranium, without materials such as cladding, alloy and structural materials) (MTHM).

Spent nuclear fuel and high-level radioactive waste [2], generated from

[1] Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing.

[2] High-level radioactive waste is the highly radioactive material resulting from reprocessing of spent nuclear fuel. It includes liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient

Continued

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DOE's national atomic energy defense and research activities, are primarily located at DOE's Hanford Reservation, the Savannah River Site, and the Idaho National Engineering Laboratory. Other spent nuclear fuel, either currently in DOE possession or which may come under DOE possession, includes material from foreign research reactors, approximately 29 domestic university reactors, 5 non-DOE research reactors, and 4 "special case" reactors at non-DOE locations.

In 1982, in response to the continued accumulation of spent nuclear fuel and high-level radioactive waste, Congress passed the NWPA. The purpose of the NWPA was to establish geologic repositories that would provide reasonable assurance that the public and the environment would be adequately protected from the hazards posed by these materials. In 1987, Congress amended the NWPA and directed DOE to evaluate the suitability of only the Yucca Mountain site in southern Nevada as a potential site for the first repository. If, based on this evaluation, the Secretary of Energy determines that the Yucca Mountain site is suitable, the Secretary may then recommend that the President approve the site for development of a repository.

Under the NWPA, DOE is prohibited from emplacing more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the first repository until such time as a second repository is in operation. The current planning basis calls for 63,000 MTHM of commercial spent nuclear fuel to be disposed of in the first repository, proposed to be located at the Yucca Mountain site. The planning basis also calls for the disposal of 7,000 MTHM equivalent of DOE-owned spent nuclear fuel and high-level radioactive waste in this first repository.

Proposed Action

If the site were found to be suitable, the proposed action would be to construct, operate, and eventually close a repository at Yucca Mountain for the geologic disposal of up to 70,000 MTHM of commercial and DOE-owned spent nuclear fuel and high-level radioactive waste. Spent nuclear fuel and high-level radioactive waste would be disposed of in the repository in a subsurface configuration that would ensure its long-term isolation from the human environment. Repository construction, operation, and closure would be governed by the Nuclear Regulatory Commission's licensing process.

Construction would begin if the Nuclear Regulatory Commission authorizes construction of the repository. Surface facilities would be designed and constructed to receive, and prepare for disposal, spent nuclear fuel and high-level radioactive waste that would arrive in transportation casks by highway and by rail. Capability to treat or package the secondary wastes generated during disposal operations would also be provided. Subsurface facilities would be designed and constructed for emplacement of spent nuclear fuel and high-level radioactive waste in disposal drifts. Subsurface facilities would primarily include access ramps, ventilation systems, disposal drifts, and equipment alcoves.

Disposal operations would begin once the Nuclear Regulatory Commission issues a license allowing receipt of spent nuclear fuel and high-level radioactive waste. Disposal operations would be expected to last up to 40 years, depending on shipment schedules. Disposal drifts would continue to be constructed during this time period as necessary. Spent nuclear fuel assemblies,[3] and canisters containing assemblies[4] or vitrified (i.e., solidified) high-level radioactive waste[5] would be shipped to the repository in transportation casks that meet the Nuclear Regulatory Commission and U.S. Department of Transportation requirements for shipping by truck or rail[6]. The assemblies would be removed from the transportation casks, which would be placed back into service after decontamination and maintenance or after necessary repairs were completed. Canisters and assemblies would be transferred to a "hot" cell—a room where remotely-controlled equipment would be used to place the material in disposal containers. These "waste packages" (i.e., assemblies and canisters in disposal containers) would be transported underground in a transportation vehicle having radiation shielding for worker protection. Monitoring equipment, which would either be placed in selected drifts or would be mobile remote-sensing devices, would monitor performance of waste packages and aspects of the local repository geology.

The closure/post-closure period would begin after the Nuclear Regulatory Commission amends the license to authorize permanent closure. Underground equipment would be removed, repository openings would be backfilled and sealed, and the surface facilities would be decontaminated, decommissioned, and dismantled or converted to other uses. Institutional controls, such as permanent markers and monuments, would be designed and constructed to last thousands of years and discourage human activities that could compromise the waste isolation capabilities of the repository.

The disposal and closure/post-closure activities would be designed and implemented so that the combination of engineered (i.e., waste package and any backfill) and natural (geologic system) barriers would isolate the spent nuclear fuel and high-level radioactive waste. The combination of barriers would meet a standard to be specified by the Environmental Protection Agency, which has been entrusted to develop a radiation release standard pursuant to Section 801 of the Energy Policy Act of 1992 (42 U.S.C. § 10141 note); individual barriers would perform according to Nuclear Regulatory Commission requirements, including its performance objectives at 10 CFR 60.113. The engineered barrier must provide substantially complete containment of spent nuclear fuel and high-level radioactive waste for between 300 and 1,000 years by using corrosion resistant materials in the waste package.

Beyond 1,000 years, continued isolation would be assisted by features that would limit the rate at which radioactive components of the waste would be released. The rate of release would be substantially affected by natural conditions, the heat generation rate of spent nuclear fuel and high-level radioactive waste (i.e., thermal load), and its rate of heat dissipation. First, different thermal loads would affect directly the internal and external waste package temperatures, thereby affecting the corrosion rate and integrity of the waste package. Second, the heat would affect the geochemistry, hydrology, and mechanical stability of the disposal drifts, which in turn would influence the flow of groundwater and the

concentrations and other highly radioactive material that the Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent isolation.

[3] A fuel assembly is made up of fuel elements held together by plates and separated by spacers attached to the fuel cladding.

[4] Under one scenario, spent nuclear fuel assemblies would be sealed in a multi-purpose canister that would then be inserted into separate casks/containers for storage, transportation, and disposal. Other canisters are available and include single-purpose systems, which require transferring of individual assemblies from one cask/container to another for storage, transport, and disposal. Another alternative would be dual-purpose systems which require storing and transporting individual assemblies in one cask and disposing of them in another container.

[5] Vitrified high-level radioactive waste would be sealed in canisters suitable for transport in a truck or train cask.

[6] Barges may also be used for intermodal shipments of spent nuclear fuel and high-level radioactive waste from generator sites to nearby locations for transfer to truck and rail.

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transport of radionuclides from the engineered and natural barrier systems to the environment. Therefore, the long-term performance of the repository would be managed by appropriately spacing the waste packages within disposal drifts and the distances between disposal drifts, and by selectively placing spent nuclear fuel and high-level radioactive waste packages to account for their individual heat generation rates.

Alternatives

DOE has preliminarily identified for analysis in the EIS a full range of reasonable implementation alternatives for the construction, operation, and closure/post-closure of a repository at Yucca Mountain. These implementation alternatives are based on thermal load objectives and include High Thermal Load, Intermediate Thermal Load, and Low Thermal Load alternatives.

Under each implementation alternative, DOE will evaluate different spent nuclear fuel and high-level radioactive waste packaging and transportation options. DOE anticipates that these options would produce the broadest range of potential configurations for both surface facilities and possible operational and disposal conditions at the repository. Evaluation of these options will identify the full range of reasonably foreseeable impacts to human health and the environment associated with each implementation alternative.

High Thermal Load Alternative

Under the High Thermal Load implementation alternative, spent nuclear fuel and high-level radioactive waste would be disposed in an underground configuration that would generate the upper range of repository temperatures while meeting performance objectives to isolate the material in compliance with Environmental Protection Agency standards and Nuclear Regulatory Commission requirements. Under this alternative, the emplacement density would likely be greater than 80 MTHM per acre. This alternative would represent the highest repository thermal loading based on available information and expected test results.

Intermediate Thermal Load Alternative

Under the Intermediate Thermal Load implementation alternative, spent nuclear fuel and high-level radioactive waste would be disposed in an underground configuration that would generate an intermediate range of repository temperatures (compared to the High and Low Thermal Load alternatives) while meeting performance objectives to isolate the material in compliance with Environmental Protection Agency standards and Nuclear Regulatory Commission requirements. Under this alternative, the disposal density would likely range between 40 to 80 MTHM per acre.

Low Thermal Load Alternative

Under the Low Thermal Load implementation alternative, spent nuclear fuel and high-level radioactive waste would be disposed in an underground configuration that would provide the lowest potential repository thermal loading (based on available information and expected test results) while meeting performance objectives to isolate the material in compliance with Environmental Protection Agency standards and Nuclear Regulatory Commission requirements. Under this alternative, the disposal density would likely be less than 40 MTHM per acre.

Packaging Options

As part of each implementation alternative, two packaging options would be evaluated. Under Option 1, spent nuclear fuel assemblies would be packaged and sealed in multi-purpose canisters at the generator sites prior to being transported to the repository in Nuclear Regulatory Commission-certified casks. High-level radioactive waste also would be packaged and sealed in canisters prior to shipment in similar casks. Under Option 2, spent nuclear fuel assemblies (without canisters) and sealed canisters of high-level radioactive waste would be transported to the repository in Nuclear Regulatory Commission-certified casks. Under both options, assemblies and canisters with intact seals would be removed from the casks and placed in disposal containers at the repository.

DOE recognizes that it is likely that a mix of spent nuclear fuel assemblies and canisters (and canister systems) of spent nuclear fuel and vitrified high-level radioactive waste would arrive at the repository during disposal operations. However, since the specific mix is speculative, the above packaging options were chosen to produce the broadest range of potential configurations for both surface facilities and possible operational and disposal conditions at the repository. These options were also selected to reflect the potential range of exposures to workers and the public at the generator sites, along transportation routes, and at the repository from the packaging, transport, and disposal of spent nuclear fuel and high-level radioactive waste.

Transportation

As part of each implementation alternative, two national transportation options and three regional (i.e., within the State of Nevada) transportation options would be evaluated. These options would be expected to result in the broadest range of operating conditions relevant to potential impacts to human health and the environment.

In a national context, the first option would consist of shipping all spent nuclear fuel and high-level radioactive waste by truck, from the generator site to the repository.

The second national option would consist of shipment by rail, except from those generator sites (as many as 19) that may not have existing capabilities to load and ship rail casks. For such sites, the spent nuclear fuel would be transported by truck to the repository, or to a facility near the nuclear power plant where it would be transferred to rail cars for shipment to the repository.

In a regional context, there are three transportation options: two of these options apply to shipments that would arrive in Nevada by rail, and the third applies to shipments that would arrive in Nevada by legal weight truck.[7]

The first regional transportation option would consist of several rail corridors to the repository. The rail corridor option would involve identifying and applying siting criteria, based on engineering considerations (e.g., topography and soils), potential land use restrictions (e.g., wilderness areas and existing conflicting uses), and any other factors identified from the scoping process.

The second regional transportation option would involve the use of heavy haul truck[8] routes to the repository. The heavy haul option would include the construction and use of an intermodal transfer facility to receive shipments that would arrive in Nevada by rail; the intermodal transfer facility would be located at the beginning of the heavy haul route. The heavy haul option would include any need to improve the local transportation infrastructure.

The third regional transportation option would involve legal weight truck shipments directly to the repository. Under this option, a transfer facility would not be required.

No Action

The No Action alternative would evaluate termination of site

[7] A legal weight truck consists of a tractor, semi-trailer, and loaded cask, with a maximum gross weight of 80,000 pounds.

[8] A heavy haul truck consists of a tractor, semi-trailer, and loaded cask, with a gross weight in excess of 129,000 pounds.

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characterization activities at Yucca Mountain and the continued accumulation of spent nuclear fuel and high-level radioactive waste at commercial storage sites and DOE facilities. Spent nuclear fuel and high-level radioactive waste would continue to be managed for the foreseeable future at existing commercial storage sites and DOE facilities located in 34 States. The No Action alternative, although contrary to the Congressional desire to provide a permanent solution for isolation of the Nation's spent nuclear fuel and high-level radioactive waste, provides a baseline against which the implementation alternatives can be compared.

At the Yucca Mountain site, the surface facilities, excavation equipment, and other support facilities would be dismantled and removed for reuse or recycling, or would be disposed of in solid waste landfills. Disturbed surface areas would be reclaimed and excavated openings to the subsurface would be sealed and backfilled.

At commercial reactors, spent nuclear fuel would continue to be generated and stored in either water pools or in canisters, until storage space at individual reactors becomes inadequate, at which time reactor operations would cease. DOE-owned spent nuclear fuel and high-level radioactive waste would continue to be managed at three primary sitesÐthe Hanford Reservation, Savannah River Site, and the Idaho National Engineering Laboratory.

Environmental Issues To Be Examined in the EIS

This EIS will examine the site-specific environmental impacts from construction, operation, and eventual closure of a repository for spent nuclear fuel and high-level radioactive waste disposal at Yucca Mountain, Nevada. Transportation-related impacts of the alternatives will also be analyzed. Through internal discussion and outreach programs with the public, DOE is aware of many environmental issues related to the construction, operation, and closure/post-closure phases of such a repository. The issues identified here are intended to facilitate public scoping. The list is not intended to be all-inclusive or to predetermine the scope of the EIS, but should be used as a starting point from which the public can help DOE define the scope of the EIS.

- Radiological and non-radiological releases. The potential effects to the public and on-site workers from radiological and nonradiological releases;
- Public and Worker Safety and Health. Potential health and safety impacts (e.g., injuries) to on-site workers during the unloading, temporary surface storage, and underground emplacement of waste packages at Yucca Mountain;
- Transportation. The potential impacts associated with national and regional shipments of spent nuclear fuel and high-level radioactive waste from reactor sites and DOE facilities to the Yucca Mountain site will be assessed. Regional transportation issues include: (a) technical feasibility, (b) socioeconomic impacts, (c) land use and access impacts, and (d) impacts of constructing and operating a rail spur, a heavy haul route, and/or a transfer facility;
- Accidents. The potential impacts from reasonably foreseeable accidents, including any accidents with low probability but high potential consequences;
- Criticality. The likelihood that a self-sustaining nuclear chain reaction could occur and its potential consequences;
- Waste Isolation. Potential impacts associated with the long-term performance of the repository;
- Socioeconomic Conditions. Potential regional (i.e., in Nevada) socioeconomic impacts to the surrounding communities, including impacts on employment, tax base, and public services;
- Environmental Justice. Potential for disproportionately high and adverse impacts on minority or low-income populations;
- Pollution Prevention. Appropriate and innovative pollution prevention, waste minimization, and energy and water use reduction technologies to eliminate or significantly reduce use of energy, water, hazardous substances, and to minimize environmental impacts;
- Soil, Water, and Air Resources. Potential impacts to soil, water quality, and air quality;
- Biological Resources. Potential impacts to plants, animals, and habitat, including impacts to wetlands, and threatened and endangered species;
- Cultural Resources. Potential impacts to archaeological/historical sites, Native American resources, and other cultural resources;
- Cumulative impacts from the proposed action and implementing alternatives and other past, present, and reasonably foreseeable future actions;
- Potential irreversible and irretrievable commitment of resources.

Under the No Action alternative, potential environmental effects associated with the shutdown of site characterization activities at Yucca Mountain will be estimated. Potential environmental effects from the continued accumulation of spent nuclear fuel and high-level radioactive waste at commercial reactors and DOE sites will be addressed by summarizing previous relevant environmental analyses and by performing new analyses of representative sites, as appropriate. At the Yucca Mountain site, the potential environmental consequences from the reclamation of disturbed surface areas, and the sealing of excavated openings following the dismantlement and removal of facilities and equipment, will be quantified. These analyses would be similar in level of detail to the analyses of the implementing alternatives. At the commercial reactor and DOE sites, the potential environmental consequences will be addressed in terms of risk to the environment and the public from long-term management of spent nuclear fuel and high-level radioactive waste. In addition, the loss of storage capacity, the need for additional capacity, and their potential consequences to continued reactor operations, will be described.

Consultations With Other Agencies

The NWPA requires DOE to solicit comments on the EIS from the Department of the Interior, the Council on Environmental Quality, the Environmental Protection Agency, and the Nuclear Regulatory Commission (42 U.S.C. § 10134(a)(1)(D)). DOE also intends to consult with the Departments of the Navy and Air Force and will solicit comments from other agencies, the State of Nevada, affected units of local government, and Native American tribal organizations, regarding the environmental issues to be addressed by the EIS.

Relationship to Other DOE NEPA Reviews

DOE is preparing or has completed other NEPA documents that may be relevant to the Office of Civilian Radioactive Waste Management Program and this EIS. If appropriate, this EIS will incorporate by reference and update information taken from these other NEPA documents. These documents (described below) are available for inspection by the public at the DOE Freedom of Information Reading Room (1E–190), Forrestal Building, 1000 Independence Ave., S.W., Washington, D.C. and will be made available in Nevada at locations to be announced at the public scoping meetings. These documents include the following:

- *Environmental Assessment, Yucca Mountain Site*, Nevada Research and

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Development Area, Nevada, DOE/RW–0073, 1986.

• *Environmental Assessment for a Monitored Retrievable Storage Facility*, DOE/RW–0035, 1986.

• *Environmental Impact Statement for a Multi-Purpose Canister System for the Management of Civilian and Naval Spent Nuclear Fuel.* The Notice of Intent was published on October 24, 1994 (59 FR 53442). The scoping process for this EIS has been completed and an Implementation Plan is being prepared. The Draft EIS is scheduled to be issued for public review in late 1995.

• *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement* [Final EIS issued April 1995 (DOE/EIS–0203–F); Record of Decision (60 FR 28680–96, June 1, 1995)]. This EIS analyzes the potential environmental consequences of managing DOE's inventory of spent nuclear fuel over the next 40 years. The Nevada Test Site was considered but was not selected as a DOE spent nuclear fuel management site.

• *Waste Management Programmatic Environmental Impact Statement* (formerly Environmental Management Programmatic EIS). A revised Notice of Intent was published January 24, 1995 (60 FR 4607). This Programmatic EIS will address impacts of potential DOE waste management actions for the treatment, storage, and disposal of waste. The Draft EIS is scheduled to be issued for public review in September 1995.

• *Environmental Impact Statement for a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* [Notice of Intent published October 21, 1993 (58 FR 54336)]. The draft EIS was issued for public review in March 1995 (DOE/EIS–0218D). This EIS addresses the potential environmental impacts of the proposed policy's implementation. Under the proposed policy, the United States could accept up to 22,700 foreign research reactor spent nuclear fuel elements over a 10–15 year period.

• *Environmental Impact Statement on the Transfer and Disposition of Surplus Highly Enriched Uranium* (formerly part of the Programmatic Environmental Impact Statement for Long-Term Storage and Disposition of Weapons-Usable Fissile Materials). The Notice of Intent was issued April 5, 1995 (60 FR 17344). This EIS will address disposition of DOE's surplus highly enriched uranium to support the President's Nonproliferation Policy. The Draft EIS is scheduled to be issued in September 1995.

• *Programmatic Environmental Impact Statement for Storage and Disposition of Weapons-Usable Fissile Materials* [Notice of Intent published June 21, 1994 (59 FR 31985)]. This Programmatic EIS will evaluate alternatives for long-term storage of all weapons-usable fissile materials (primarily plutonium and highly enriched uranium retained for strategic purposes—not surplus) and disposition of surplus weapons-usable fissile materials (excluding highly enriched uranium), so that risk of proliferation is minimized. The Nevada Test Site is a candidate storage site.

• *Tritium Supply and Recycling Programmatic Environmental Impact Statement.* A revised Notice of Intent was published October 28, 1994 (59 FR 54175), and the Draft Programmatic EIS was issued in March 1995 (60 FR 14433, March 17, 1995). Public hearings on the Draft Programmatic EIS were held in April 1995, and a Final Programmatic EIS is scheduled for October 1995. This EIS addresses how to best assure an adequate tritium supply and recycling capability. The Nevada Test Site is an alternative site for new tritium supply and recycling facilities.

• *Stockpile Stewardship and Management Programmatic Environmental Impact Statement.* A Notice of Intent was published June 14, 1995 (60 FR 31291). A prescoping workshop was held on May 19, 1995, and scoping meetings are scheduled to be held during July and August 1995. This Programmatic EIS will evaluate proposed future missions of the Stockpile Stewardship and Management Program and potential configuration (facility locations) of the nuclear weapons complex to accomplish the Stockpile Stewardship and Management Program missions. The Nevada Test Site is an alternative site for potential location of new or upgraded Stockpile Stewardship and Management Program facilities.

• *Site-Wide Environmental Impact Statement for the Nevada Test Site* [Notice of Intent published August 10, 1994 (59 FR 40897)]. This EIS will address resource management alternatives for the Nevada Test Site to support current and potential future missions involving defense programs, research and development, waste management, environmental restoration, infrastructure maintenance, transportation of wastes, and facility upgrades and alternative uses. The public scoping process has been completed, and the Implementation Plan was issued in July 1995. The Draft EIS is scheduled to be issued for public review in September 1995.

• *Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapon Components* [Notice of Intent published May 23, 1994 (59 FR 26635); an amended Notice of Intent published June 23, 1995 (60 FR 32661)]. This EIS will address the potential environmental impacts of the continued operation of the Pantex Plant, which includes near- to mid-term foreseeable activities and the nuclear component storage activities at other DOE sites associated with nuclear weapon disassembly operations at the Pantex Plant. The Nevada Test Site is being considered as an alternative site for relocation of interim plutonium pit storage.

Public Reading Rooms

Copies of the Implementation Plan, and the Draft and Final EISs, will be available for inspection during normal business hours at the following public reading rooms. DOE may establish additional information locations and will provide an updated list at the public scoping meetings.

Albuquerque Operations Office, National Atomic Museum, Bldg. 20358, Wyoming Blvd., S.E., Kirtland Air Force Base, Albuquerque, NM 87117. Attn: Diane Leute (505) 845–4378

Atlanta Support Office, U.S. Dept. of Energy, Public Reading Room, 730 Peachtree Street, Suite 876, Atlanta, GA 30308–1212. Attn: Nancy Mays/Laura Nicholas (404) 347–2420

Bartlesville Project Office/National Institute for Petroleum and Energy Research, Library, U.S. Dept. of Energy, 220 Virginia Avenue, Bartlesville, OK 74003. Attn: Josh Stroman (918) 337–4371

Bonneville Power Administration, U.S. Dept. of Energy, BPA–C–KPS–1, 905 N.E. 11th Street, Portland, OR 97208. Attn: Sue Ludeman (503) 230–7334

Chicago Operations Office, Document Dept., University of Illinois at Chicago, 801 South Morgan Street, Chicago, IL 60607. Attn: Seth Nasatir (312) 996–2738

Dallas Support Office, U.S. Dept. of Energy, Public Reading Room, 1420 Mockingbird Lane, Suite 400, Dallas, TX 75247. Attn: Gailene Reinhold (214) 767–7040

Fernald Area Office, U.S. Dept. of Energy, Public Information Room, FERMCO, 7400 Willey Road, Cincinnati, OH 45239. Attn: Gary Stegner (513) 648–3153

Headquarters Office, U.S. Dept. of Energy, Room 1E–190, Forrestal Bldg.,

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1000 Independence Avenue, S.W., Washington, D.C. 20585. Attn: Gayla Sessoms (202) 586–5955
Idaho Operations Office, Idaho Public Reading Room, 1776 Science Center Dr., Idaho Falls, ID 83402. Attn: Brent Jacobson (208) 526–1144
Kansas City Support Office, U.S. Dept. of Energy, Public Reading Room, 911 Walnut Street, 14th Floor, Kansas City, MO 64106. Attn: Anne Scheer (816) 426–4777
Office of Civilian Radioactive Waste Management National Information Center, 600 Maryland Avenue, S.W., Suite 760, Washington, D.C. 20024. Attn: Paul D'Anjou (202) 488–6720
Oak Ridge Operations Office, U.S. Dept. of Energy, Public Reading Room, 55 South Jefferson Circle, Room 112, Oak Ridge, TN 37831–8510. Attn: Amy Rothrock (615) 576–1216
Oakland Operations Office, U.S. Dept. of Energy, Public Reading Room, EIC, 8th Floor, 1301 Clay Street, Room 700N, Oakland, CA 94612–5208. Attn: Laura Noble (510) 637–1762
Pittsburgh Energy Technology Center, U.S. Dept. of Energy, Bldg. 922/M210, Receiving Department, Building 166, Cochrans Mill Road, Pittsburgh, PA 15236–0940. Attn: Ann C. Dunlap (412) 892–6167
Richland Operations Office, U.S. Dept. of Energy, Public Reading Room, 100 Sprout Rd., Room 130 West, Mailstop H2–53, Richland, WA 99352. Attn: Terri Traub (509) 376–8583
Rocky Flats Field Office, Front Range Community College Library, 3645 West 112th Avenue, Westminster, CO 80030. Attn: Nancy Ben (303) 469–4435
Savannah River Operations Office, Gregg-Graniteville Library, University of S. Carolina-Aiken, 171 University Parkway, Aiken, SC 29801. Attn: James M. Gaver (803) 725–2889
Southeastern Power Administration, U.S. Dept. of Energy, Legal Library, Samuel Elbert Bldg., 2 South Public Square, Elberton, GA 30635–2496. Attn: Joel W. Seymour/Carol M. Franklin (706) 213–3800
Southwestern Power Administration, U.S. Dept. of Energy, Public Reading Room, 1 West 3rd, Suite 1600, Tulsa, OK 74103. Attn: Marti Ayers (918) 581–7426
Strategic Petroleum Reserve Project Management Office, U.S. Dept. of Energy, SPRPMO/SEB Reading Room, 900 Commerce Road East, New Orleans, LA 70123. Attn: Ulysess Washington (504) 734–4243
Yucca Mountain Science Centers
Yucca Mountain Science Center, U.S. 95—Star Route 374, Beatty, NV 89003. Attn: Marina Anderson (702) 553–2130
Yucca Mountain Science Center, 4101–B Meadows Lane, Las Vegas, NV 89107. Attn: Melinda D'ouville (702) 295–1312
Yucca Mountain Science Center, 1141 South Hwy. 160, Pahrump, NV 89041. Attn: Lee Krumm (702) 727–0896

TABLE 1.—SCOPING MEETINGS

Location of scoping meeting	Dates/times [1]
Pahrump Community Center, 400 N. Hwy. 160, Pahrump, NV 89048	Tuesday, August 29, 1995, morning/evening sessions.
Boise Centre on the Grove, 850 W. Front St., Boise, ID 83702	Wednesday, September 6, 1995, morning/evening sessions.
Lawlor Events Center, University of Nevada-Reno Campus, Reno, NV 89667.	Friday, September 8, 1995, morning/evening sessions.
University of Chicago, Downtown MBA Center, 450 N. Cityfront Plaza Drive, Chicago, IL 60611.	Tuesday, September 12, 1995, morning/evening sessions.
Cashman Field, 850 Las Vegas Blvd. North, Las Vegas, NV 89101	Friday, September 15, 1995, morning/evening sessions .
Denver Convention Complex, 700 14th Street, Denver, CO 80202	Tuesday, September 19, 1995, afternoon/evening sessions.
Sacramento Public Library, 828 I Street, Sacramento, CA 95814	Thursday, September 21, 1995, afternoon/evening sessions.
Arlington Community Center, 2800 South Center Street, Dallas, TX 76004.	Tuesday, September 26, 1995, afternoon/evening sessions.
Caliente Youth Center, Highway 93, Caliente, NV 89008	Thursday, September 28, 1995, morning/evening sessions.
Hilton Inn, 150 West 500 South, Salt Lake City, UT 84111	Thursday, October 5, 1995, afternoon/evening sessions.
Maritime Institute of Technology and Graduate Studies, 5700 Hammonds Ferry Rd., Linthicum (near Baltimore), MD 21090.	Wednesday, October 11, 1995, morning/evening sessions.
Russell Sage Conference Center, 45 Ferry St., Troy (Albany), NY 12180.	Friday, October 13, 1995, afternoon/evening sessions.
Georgia International Convention Center, 1902 Sullivan Road, College Park (Atlanta), GA 30337.	Tuesday, October 17, 1995, morning/evening sessions.
Penn Valley Community College, 3201 S.W. Trafficway, Kansas City, MO 64111.	Friday, October 20, 1995, afternoon/evening sessions.
Tonopah Convention Center, 301 Brougher, Tonopah, NV 89049	Tuesday, October 24, 1995, morning/evening sessions.

[1] Session times are as follows: Morning (8:30 a.m.–12:30 p.m.), Afternoon (12:00 a.m.–4:00 p.m.), Evening (6:00 p.m.–10:00 p.m.).

Issued in Washington, D.C., this 1st day of August, 1995.

Peter N. Brush,

Acting Assistant Secretary, Environment, Safety and Health.

[FR Doc. 95–19396 Filed 8–4–95; 8:45 am]

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DEPARTMENT OF ENERGY

Floodplain and Wetlands Involvement; Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

AGENCY: Department of Energy.

ACTION: Notice of floodplain and wetlands involvement.

SUMMARY: The U.S. Department of Energy (DOE) is proposing to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nye County, Nevada. As part of its proposal, DOE is considering shipping spent nuclear fuel and high-level radioactive waste in the State of Nevada over a rail line that would be constructed or over an existing highway route that may need upgrading to accommodate heavy-haul trucks. Portions of the rail corridor or highway route would cross perennial and ephemeral streams and their associated floodplains, as well as possible wetlands. Furthermore, portions of the transportation system in the immediate vicinity of the proposed repository would be located within the 100-year floodplains of Midway Valley Wash, Drillhole Wash, Busted Butte Wash and/or Fortymile Wash. No other aspect of repository-related operations or nuclear or nonnuclear repository facilities would be located within the 500-year or 100-year floodplains of these washes. In accordance with DOE regulations for Compliance with Floodplain/Wetlands Environmental Review Requirements (10 CFR Part 1022), DOE will prepare a floodplain and wetlands assessment commensurate with proposed decisions and available information. The assessment will be included in the Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada. A draft of this EIS is scheduled to be published during the summer of 1999.

DATES: The public is invited to comment on this notice on or before July 1, 1999. Comments received after this date will be considered to the extent practicable.

ADDRESSES: Comments on this notice should be addressed to Ms. Wendy Dixon, EIS Project Manager, Yucca Mountain Site Characterization Office,

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U.S. Department of Energy, P.O. Box 30307, M/S 010, Las Vegas, Nevada 89036–0307. Comments also can be submitted via electronic mail to: eisr@notes.ymp.gov.

FOR FURTHER INFORMATION CONTACT:

Proposed Action: Ms. Wendy Dixon, EIS Project Manager, at the above address, or by calling (800)–881–7292.

Floodplain and Wetlands Environmental Review Requirements: Ms. Carol Borgstrom, Office of NEPA Policy and Assistance (EH–42), U.S. Department of Energy, 1000 Independence Avenue, S.W., Washington, D.C. 20585, (202)–586–4600 or leave a message at (800) 472–2756.

SUPPLEMENTARY INFORMATION: In accordance with the Nuclear Waste Policy Act, as amended, DOE is studying Yucca Mountain in Nye County, Nevada, to determine its suitability for the deep geologic disposal of commercial and DOE spent nuclear fuel and high-level radioactive waste. In 1989, DOE published a Notice of Floodplain/Wetlands Involvement (54 FR 6318, February 9, 1989) for site characterization at Yucca Mountain, and in 1992 published a Floodplain Statement of Findings (57 FR 48363, October 23, 1992).

DOE is now preparing an EIS (DOE–EIS–0250) to assess the potential environmental impacts from the construction, operation and monitoring, and eventual closure of the proposed geologic repository. DOE issued a Notice of Intent to prepare the EIS on August 7, 1995 (60 FR 40164). As part of its proposal, DOE is considering shipping spent nuclear fuel and high-level radioactive waste in the State of Nevada over a rail line that would be constructed or over an existing highway route that may need upgrading to accommodate heavy-haul trucks. For the rail mode, DOE is evaluating five potential corridors (Figure 1). For the heavy-haul truck mode, DOE is evaluating three potential locations for an intermodal transfer station associated with five potential highway routes (Figure 2; an intermodal transfer station is a facility at which shipping casks containing spent nuclear fuel and high-level radioactive waste would be transferred from trains to trucks, and empty shipping casks would be transferred from trucks to trains). The rail corridors would be about 400 meters (0.25 mile) wide. The Carlin Corridor would be the longest at 520 kilometers (323 miles) followed by the Caliente (513 kilometers, 319 miles), Caliente-Chalk Mountain (345 kilometers, 214 miles), Jean (181 kilometers, 112 miles), and Valley Modified (159 kilometers, 98 miles) corridors. The heavy-haul routes would utilize existing roads and rights-of-ways which typically would be less than 400 meters (0.25 miles) in width. The Caliente Route would be the longest at 533 kilometers (331 miles) followed by the Caliente-Las Vegas (377 kilometers, 234 miles), Caliente-Chalk Mountain (282 kilometers, 175 miles), Sloan/Jean (190 kilometers, 118 miles) and Apex/Dry Lake (183 kilometers, 114 miles) routes.

Portions of the transportation system in the immediate vicinity of the proposed repository are likely to be located within the 100-year floodplains of Midway Valley Wash, Drillhole Wash, Busted Butte Wash and/or Fortymile Wash (Figure 3). Fortymile Wash, a major wash that flows to the Amargosa River, drains the eastern side of Yucca Mountain. Midway Valley Wash, Drillhole Wash and Busted Butte Wash are tributaries to Fortymile Wash. Although water flow in Fortymile Wash and its tributaries is rare, the area is subject to flash flooding from thunderstorms and occasional sustained precipitation. There are no naturally occurring wetlands near the proposed repository facilities, although there are two man-made well ponds in Fortymile Wash that support riparian vegetation.

If the Proposed Action were implemented, DOE would use an existing road during construction of the repository that crosses the 100-year floodplain of Fortymile Wash (Figure 3). This road and other features of site characterization that involve floodplains have previously been examined by DOE and a Statement of Findings was issued in 1992 (57 FR 48363, October 23, 1992). It is uncertain at this time whether this existing road would require upgrading to accommodate the volume and type of construction vehicles.

In addition, transportation infrastructure would be constructed either in Midway Valley Wash, Drillhole Wash and Busted Butte Wash, or in Midway Valley Wash, Drillhole Wash and Fortymile Wash. The decision on which washes would be involved is dependent on future decisions regarding the mode of transport (rail or truck) which, in turn, would require the selection of one rail corridor or the selection of one site for an intermodal transfer station and its associated heavy-haul route. Structures that might be constructed in a floodplain could include one or more bridges to span the washes, one or more roads that could pass through the washes, or a combination of roads and culverts in the washes. No other aspect of repository-related operation of nuclear or nonnuclear facilities would be located within 500-year or 100-year floodplains.

Outside of the immediate vicinity of the proposed repository, the five rail corridors, and the three sites for an intermodal transfer station and associated five heavy-haul routes, would cross perennial and ephemeral streams, and possibly wetlands. It is likely that a combination of bridges, roads and culverts, or other engineered features, would be needed to span or otherwise cross the washes and possible wetlands, although the location of such structures is uncertain at this time.

DOE will prepare an initial floodplain and wetlands assessment commensurate with the proposed decisions and available information. This assessment will be included in the Draft EIS that is scheduled to be issued for public comment later this summer. If, after a possible recommendation by the Secretary of Energy, the President considers the site qualified for an application to the U.S. Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. If the site designation becomes effective, the Secretary of Energy will submit to the Nuclear Regulatory Commission a License Application for a construction authorization. DOE would then probably select a rail corridor or a site for an intermodal transfer station among those considered in the EIS. Following such a decision, additional field surveys, environmental and engineering analyses, and National Environmental Policy Act reviews would likely be needed regarding a specific rail alignment for the selected corridor or the site for the intermodal transfer station and its associated heavy-haul truck route. When more specific information becomes available about activities proposed to take place within floodplains and wetlands, DOE will conduct further environmental review in accordance with 10 CFR Part 1022. Information that would be considered in a subsequent assessment includes, for example, the identification of 500-year and 100-year floodplains among feasible alignments of the selected rail corridor or the site of the intermodal transfer station and its associated heavy-haul route, identification of individual wetlands, and whether the floodplains and wetlands could be avoided. If the floodplains and wetlands could not be avoided, information on specific engineering designs and associated construction activities in the floodplains and wetlands also would be needed to permit a more detailed assessment and

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to ensure that DOE minimizes potential harm to or within any affected floodplains or wetlands.

Issued in Las Vegas, Nevada, on the 4th day of June 1999.

Wendy Dixon,

EIS Project Manager.

BILLING CODE 6450–01–P

48996 **Federal Register** / Vol. 64, No. 174 / Thursday, September 9, 1999 / Notices

DEPARTMENT OF ENERGY

Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

AGENCY: Office of Civilian Radioactive Waste Management, Department of Energy.

ACTION: Notice of Public Hearings.

SUMMARY: On August 13, 1999, the U.S. Department of Energy (DOE) published a Notice of Availability (64 FR 44200) of its Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DOE/EIS–0250–D) and announced a 180-day public comment period ending February 9, 2000. The Draft EIS provides information on potential environmental impacts that could result from a proposed action to construct, operate and monitor, and eventually close a repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain in Nye County, Nevada.

The public is invited to submit written and oral comments at the 16 public hearings listed at the end of this notice.

DATES: DOE will consider all comments transmitted or postmarked by February 9, 2000. Comments submitted after this date will be considered to the extent practicable.

ADDRESSES: Written comments should be directed to: Ms. Wendy R. Dixon, EIS Project Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, NV 89036–0307.

Written comments may be transmitted by facsimile to 1–800–967–0739 and should include the following identifier: "Yucca Mountain Draft EIS."

Written comments may be submitted over the Internet via the Yucca Mountain Project website at *http://www.ymp.gov*, under the listing "Environmental Impact Statement."

FOR FURTHER INFORMATION CONTACT: Ms. Wendy R. Dixon, EIS Project Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, NV 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

SUPPLEMENTARY INFORMATION: Copies of the Draft EIS have been provided to federal, state, tribal, and local government agencies and interested parties. In addition, the Draft EIS is available on the internet via the DOE National Environmental Policy Act (NEPA) website at *http://www.tis.eh.doe.gov/nepa* under the listing DOE NEPA Analyses, the Yucca Mountain Project website at *http://www.ymp.gov* under the listing Environmental Impact Statement, and at 38 public reading rooms across the country. Copies of the Draft EIS may be requested by calling 1–800–967–3477.

A complete set of all hard copy references used in the preparation of the Draft EIS are available for review at four public reading rooms: University of Nevada—Las Vegas, Nevada; University of Nevada—Reno, Nevada; Yucca Mountain Science Center—Pahrump, Nevada; and the DOE Headquarters Office in Washington, DC. Noncopyrighted references are available in the Yucca Mountain Science Center in Beatty, Nevada, as well as on CD-ROMs in an additional 33 public reading rooms across the nation. Noncopyrighted references are also available on the Yucca Mountain Project website at *http://www.ymp.gov*.

The public is invited to submit written and oral comments at the 16 public hearings listed at the end of this notice. The first hour of each hearing will include a brief overview presentation on the Draft EIS and a question and answer session. The remainder of the hearing will be an opportunity to provide comments for the record. To schedule a time to provide oral comments during the hearings, please call 1–800–967-3477. Persons wishing to provide oral comments who have not registered in advance may register at each hearing.

Public hearings will be held on the following dates at the following locations:

1. September 27, 1999, 11:00 am–2:00 pm, 6:00 pm–10:00 pm, Amargosa Valley Community Center, 821 East Farm Road, Amargosa Valley, Nevada 89020.
2. September 30, 1999, 11:00 am–2:00 pm, 6:00 pm–10:00 pm, Bob Ruud Community Center, 150 North Highway 160, Pahrump, Nevada 89048.
3. October 4, 1999, 10:00 am–1:00 pm, 6:00 pm–10:00 pm, Goldfield Community Center, 403 Crook Street, Goldfield, Nevada 89013.
4. October 5, 1999, 10:00 am–1:00 pm, 6:00 pm–10:00 pm, Boise Centre on the Grove, 850 West Front Street, Boise, Idaho 83702.
5. October 19, 1999, 10:00 am–1:00 pm, 4:00 pm–8:00 pm, Bristlecone Convention Center, 150 Sixth Street, Ely, Nevada 89301.
6. October 21, 1999, 12:00 pm–3:00 pm, 6:00 pm–10:00 pm, Georgia International Convention Center, 1902 Sullivan Road, College Park, Georgia 30337.
7. October 26, 1999, 11:00 am–2:00 pm, 6:00 pm–10:00 pm, Hall of States, 444 North Capitol Street, N.W., Washington, DC 20001.
8. November 4, 1999, 12:00 pm–3:00 pm, 7:00 pm–10:00 pm, Statham Hall, 138 North Jackson Street, Lone Pine, California 93545.
9. November 9, 1999, 12:00 pm–3:00 pm, 6:00 pm–10:00 pm, Caliente Youth Center, U.S. Highway 93 North, Caliente, Nevada 89008.
10. November 16, 1999, 11:00 am–2:00 pm, 6:00 pm–10:00 pm, Denver

Convention Complex, 700 14th Street, Denver, Colorado 80202.

11. December 1, 1999, 12:00 pm–3:00 pm, 6:00 pm–10:00 pm, Lawlor Events Center, 1664 North Virginia Street, Reno, Nevada 89557.

12. December 7, 1999, 11:00 am–2:00 pm, 5:30 pm–9:30 pm, Austin Town Hall, 137 Court Street, Austin, Nevada 89310.

13. December 9, 1999, 10:00 am–1:00 pm, 6:00 pm–10:00 pm, Crescent Valley Town Hall, 5045 Tenabo Avenue, Crescent Valley, Nevada 89821.

14. January 11, 2000, 11:00 am–2:00 pm, 6:00 pm–10:00 pm, Grant Sawyer State Building, 555 East Washington, Las Vegas, Nevada 89101.

15. January 13, 2000, 10:00 am–1:00 pm, 6:00 pm–10:00 pm, Salt Lake City Hilton Inn, 150 West 500 South, Salt Lake City, Utah 84101.

16. January 20, 2000, 11:00 am–2:00 pm, 6:00 pm–10:00 pm, America's Center, 701 Convention Plaza, St. Louis, Missouri 63101.

Issued in Washington, DC, Sept. 2, 1999.

Ronald A. Milner,

Acting Deputy Director, Office of Civilian Radioactive Waste Management.

[FR Doc. 99–23420 Filed 9–8–99; 8:45 am]

BILLING CODE 6450–01–P

55260 Federal Register / Vol. 64, No. 196 / Tuesday, October 12, 1999 / Notices

DEPARTMENT OF ENERGY

Additional Public Hearing for Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV

AGENCY: Office of Civilian Radioactive Waste Management (OCRWM), Department of Energy (DOE).

ACTION: Notice of additional public hearing.

SUMMARY: On August 13, 1999, the U.S. Department of Energy (DOE) published a Notice of Availability (64 FR 44200) of its Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DOE/EIS–0250–D) and announced a 180-day public comment period ending February 9, 2000. Subsequently, 16 public hearings were announced on September 9, 1999 (64 FR 48996). DOE is now announcing one additional public hearing. To schedule a time to provide oral comments during the hearings, please call 1–800–967–3477. Persons wishing to provide oral comments who have not registered in advance may register at the hearings.

DATES: The additional public hearing will be held on December 2, 1999, from 12:00 noon to 3:00 p.m. and from 6:00 p.m. to 10:00 p.m., in Carson City, Nevada.

ADDRESSES: The additional public hearing will be held at the following location: Carson City, Nevada—Nevada State Legislature, Room 4100, 401 South Carson Street, Carson City, Nevada 89701.

FOR FURTHER INFORMATION CONTACT: Ms. Wendy R. Dixon, EIS Project Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, NV 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

SUPPLEMENTARY INFORMATION: Public hearings have been scheduled for the following dates at the following locations:

1. September 27, 1999, 11:00 am—2:00 pm, 6:00 pm—10:00 pm, Amargosa Valley Community Center, 821 East Farm Road, Amargosa Valley, Nevada 89020
2. September 30, 1999, 11:00 am—2:00 pm, 6:00 pm—10:00 pm, Bob Ruud Community Center, 150 North Highway 160, Pahrump, Nevada 89048
3. October 4, 1999, 10:00 am—1:00 pm, 6:00 pm—10:00 pm, Goldfield Community Center, 403 Crook Street, Goldfield, Nevada 89013
4. October 5, 1999, 10:00 am—1:00 pm, 6:00 pm—10:00 pm, Boise Centre on the Grove, 850 West Front Street, Boise, Idaho 83702
5. October 19, 1999, 10:00 am—1:00 pm, 4:00 pm—8:00 pm, Bristlecone Convention Center, 150 Sixth Street, Ely, Nevada 89301
6. October 21, 1999, 12:00 pm—3:00 pm, 6:00 pm—10:00 pm, Georgia International Convention Center, 1902 Sullivan Road, College Park, Georgia 30337
7. October 26, 1999, 11:00 am—2:00 pm, 6:00 pm—10:00 pm, Hall of States, 444 North Capitol Street, N.W., Washington, DC 20001
8. November 4, 1999, 12:00 pm—3:00 pm, 7:00 pm—10:00 pm, Statham Hall, 138 North Jackson Street, Lone Pine, California 93545
9. November 9, 1999, 12:00 pm—3:00 pm, 6:00 pm—10:00 pm, Caliente Youth Center, U.S. Highway 93 North, Caliente, Nevada 89008
10. November 16, 1999, 11:00 am—2:00 pm, 6:00 pm—10:00 pm, Denver Convention Complex, 700 14th Street, Denver, Colorado 80202
11. December 1, 1999, 12:00 pm—3:00 pm, 6:00 pm—10:00 pm, Lawlor Events Center, 1664 North Virginia Street, Reno, Nevada 89557
12. December 2, 1999, 12:00 pm—3:00 pm, 6:00 pm—10:00 pm, Nevada State Legislature, Room 4100, 401 South Carson Street, Carson City, Nevada 89701
13. December 7, 1999, 11:00 am—2:00 pm, 5:30 pm—9:30 pm, Austin Town Hall, 137 Court Street, Austin, Nevada 89310
14. December 9, 1999, 10:00 am—1:00 pm, 6:00 pm—10:00 pm, Crescent Valley Town Hall, 5045 Tenabo Avenue, Crescent Valley, Nevada 89821
15. January 11, 2000, 11:00 amÐ2:00 pm, 6:00 pm—10:00 pm, Grant Sawyer State Building, 555 East Washington, Las Vegas, Nevada 89101
16. January 13, 2000, 10:00 am—1:00 pm, 6:00 pm—10:00 pm, Salt Lake City Hilton Inn, 150 West 500 South, Salt Lake City, Utah 84101
17. January 20, 2000, 11:00 am—2:00 pm, 6:00 pm—10:00 pm, America's Center, 701 Convention Plaza, St. Louis, Missouri 63101

Issued in Washington, DC, October 4, 1999.

Lake Barrett,

Acting Director, Office of Civilian Radioactive Waste Management.

[FR Doc. 99–26552 Filed 10–8–99; 8:45 am]

BILLING CODE 6450–01–P

442 **Federal Register** / Vol. 65, No. 3 / Wednesday, January 5, 2000 / Notices

DEPARTMENT OF ENERGY

Additional Public Hearings for Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV

AGENCY: Office of Civilian Radioactive Waste Management, Department of Energy.

ACTION: Notice of additional public hearings.

SUMMARY: On August 13, 1999, the U.S. Department of Energy (DOE) published a Notice of Availability (64 FR 44200) of its *Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS–0250–D) and announced a 180-day public comment period ending February 9, 2000. Subsequently, 16 public hearings were announced on September 9, 1999 (64 FR 48996), and one additional hearing was announced on October 12, 1999 (64 FR 55260). DOE is now announcing three additional public hearing locations: Lincoln, NE; Cleveland, OH; and Chicago, IL. To schedule a time to provide oral comments during these hearings, please call 1–800–967–3477. Persons wishing to provide oral comments who have not registered in advance may register at the hearings.

DATES: The three additional public hearings will be held from 11:00 a.m. until 2:00 p.m. and from 6:00 p.m. until 9:00 p.m. on the following dates at the following locations: January 24, 2000, in Lincoln, NE; January 28, 2000, in Cleveland, OH; and February 1, 2000, in Chicago, IL.

ADDRESSES: The three additional public hearings will be held at the following locations:

Lincoln, NE, Ramada Inn—Airport, 1101 West Bond Street, Lincoln, Nebraska 68521
Cleveland, OH, Holiday Inn Lakeside City Center, 1111 Lakeside Avenue, Cleveland, Ohio 44114
Chicago, IL, Hotel Intercontinental, 505 North Michigan Avenue, Chicago, Illinois 60611

FOR FURTHERINFORMATION CONTACT : Ms. Wendy R. Dixon, EIS Program Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, NV 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739. Copies of the document may also be requested by telephone (1–800–967–3477) or over the Internet via the Yucca Mountain Project website at *http://www.ymp.gov*, under the listing "Environmental Impact Statement."

Issued in Washington, DC, December 29, 1999.

Ivan Itkin,

Director, Office of Civilian Radioactive Waste Management.

[FR Doc. 00–192 Filed 1–4–00; 8:45 am]

BILLING CODE 6717–01–P

44200 **Federal Register** / Vol. 64, No. 156 / Friday, August 13, 1999 / Notices

DEPARTMENT OF ENERGY

Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV

AGENCY: Office of Civilian Radioactive Waste Management, Department of Energy.

ACTION: Notice of availability.

SUMMARY: The Department of Energy (DOE) announces the availability of the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DOE/EIS–0250D). The Department has prepared this Draft EIS in accordance with the Nuclear Waste Policy Act of 1982, as amended (NWPA), the National Environmental Policy Act of 1969 (NEPA), the Council on Environmental Quality (CEQ) regulations that implement the procedural provisions of NEPA (40 CFR Parts 1500–1508), and the DOE procedures implementing NEPA (10 CFR Part 1021). The Draft EIS provides information on potential environmental impacts that could result from a Proposed Action to construct, operate and monitor, and eventually close a repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain in Nevada. The Draft EIS also considers the potential environmental impacts from an alternative referred to as the No-Action Alternative, under which a repository would not be developed at Yucca Mountain. The locations of the public hearings to receive comments on the Draft EIS are listed below.

DATES: Comments on the Draft EIS will be accepted during a 180-day public comment period, which ends on February 9, 2000. DOE will consider comments received after February 9, 2000, to the extent practicable. DOE will conduct public hearings on the Draft EIS and will announce the dates in the **Federal Register** in the near future.

ADDRESSES: Written comments, requests for further information on the Draft EIS or the public hearings, and requests for copies of the document (or a CD–ROM version) should be directed to: Ms. Wendy R. Dixon, EIS Project Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, Nevada 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

Written comments transmitted by facsimile should include the following identifier: "Yucca Mountain Draft EIS." Addresses of the locations where the Draft EIS will be available for public review are listed in this Notice under "Availability of the Draft EIS."

Written comments or requests for copies of the document may also be submitted over the Internet via the Yucca Mountain Project website at *http://www.ymp.gov*, under the listing "Environmental Impact Statement."

FOR FURTHER INFORMATION CONTACT:

Ms. Wendy R. Dixon, EIS Project Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, Nevada 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

General information on the DOE NEPA process may be requested from: Ms. Carol M. Borgstrom, Director, Office of NEPA Policy and Assistance (EH–42), U.S. Department of Energy, 1000 Independence Ave., SW, Washington, DC 20585, Telephone 1–202–586–4600, or leave a message at 1–800–472–2756.

SUPPLEMENTARY INFORMATION:

Background

On August 7, 1995, the Department published a Notice of Intent (60 FR 40164) to prepare an Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada. The purpose of the Notice of Intent was to inform the public of the proposed scope of the Repository EIS, to solicit public input, and to announce that scoping meetings would be held from August through October 1995. During that period, 15 public scoping meetings were held throughout the United States to obtain public comments regarding the scope, alternatives, and issues that should be addressed in the EIS. The scoping period closed on December 5, 1995. Due to subsequent budget reductions, EIS activities were deferred until Fiscal Year 1997. In May 1997, DOE published Summary of Public Scoping Comments Related to the Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-level Radioactive Waste at Yucca Mountain, Nye County, Nevada, which summarized the comments received by DOE during the scoping process and described how DOE planned at that time to address issues raised during scoping. A Notice of Availability for the Summary of Public Scoping Comments document was published on July 9, 1997 (62 FR 36789).

Alternatives Considered

The Draft EIS evaluates a Proposed Action and a No-Action Alternative. Under the Proposed Action, DOE would construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of as much as 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste. The Proposed Action includes the transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain from commercial and DOE sites. Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain, and commercial and DOE sites would

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continue to store spent nuclear fuel and high-level radioactive waste, packaged as necessary for their safe on-site management.

DOE developed implementing alternatives and analytical scenarios for estimating in the Draft EIS the reasonably foreseeable environmental impacts that could result from the Proposed Action. For example, DOE evaluated three thermal load scenarios, which correspond to a relatively high emplacement density of spent nuclear fuel and high-level radioactive waste (high thermal load—85 MTHM per acre), a relatively low emplacement density (low thermal load—25 MTHM per acre), and an intermediate case—60 MTHM per acre. DOE recognizes, however, that if the site is eventually approved for development of a repository, the designs of repository surface and subsurface facilities, and plans for the construction, operation and monitoring, and closure of the repository would continue to evolve and would depend on the outcome of the Nuclear Regulatory Commission's licensing review of the repository.

Two national transportation scenarios are evaluated in the Draft EIS. The mostly legal-weight truck [1] scenario assumes that most spent nuclear fuel and high-level radioactive waste would be shipped to the repository by legal-weight truck over existing highways, with a few exceptions. The mostly rail scenario assumes that most spent nuclear fuel and high-level radioactive waste would be shipped to Nevada by rail, with a few exceptions (based largely on the on-site loading limitations at some commercial sites). The Nevada transportation implementing alternatives parallel the national transportation scenarios; however, because no rail access currently exists to the repository site, the EIS considers different implementing alternatives for the construction of either a new branch rail line to the proposed repository, or an intermodal transfer station [2] with associated highway improvements for heavy-haul trucks.[3]

The No-Action Alternative considers two scenarios. Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the 72 commercial and 5 DOE sites under effective institutional control for at least 10,000 years. Scenario 2 also assumes spent nuclear fuel and high-level radioactive waste would remain at the 77 sites, but under effective institutional control for only about 100 years.

[1] Truck with a gross vehicle weight (both truck and cargo) of less than 80,000 pounds.

[2] An intermodal transfer station is a facility at the juncture of rail and road transportation used to transfer shipping casks containing spent nuclear fuel and high-level radioactive waste from rail to truck and empty casks from truck to rail.

[3] Shipment of a rail cask (weighing up to 300,000 pounds) on a special truck and trailer combination that would have a total weight of approximately 500,000 pounds.

Public Hearings and Invitation To Comment

The public is invited to provide oral and written comments on the Repository Draft EIS during the public comment period that ends on February 9, 2000. DOE will consider comments received during the comment period in preparation of the Final EIS. Comments received after February 9, 2000, will be considered to the extent practicable.

The Department will hold 16 public hearings (each following the same format in either the mid-morning or afternoon and evening) to receive oral and written comments from members of the public. The public hearings are currently planned to be held in the following Nevada locations: Pahrump, Goldfield, Caliente, Las Vegas, Reno, Austin, Crescent Valley, Amargosa Valley and Ely. Other hearing locations will include Washington, DC; Atlanta, Georgia; Denver, Colorado; Boise, Idaho; Salt Lake City, Utah; St. Louis, Missouri; and Lone Pine, California. DOE will publish the dates, times, and specific locations in the **Federal Register**, and will notify all recipients of the Draft EIS and the media in writing as soon as this information is available. In addition, this information will be available on the Yucca Mountain website at *http://www.ymp.gov* and on the toll-free information line at 1–800–967–3477.

Each of the public hearings will include a brief session in which an overview of the Draft EIS will be presented, a general question-and-answer session, and an opportunity to provide comments for the record. Members of the public who plan to present oral comments are asked to register in advance by calling 1–800–967–3477.

Availability of the Draft EIS

Copies of the Draft EIS are being distributed to Federal, State, Indian tribal, and local officials, agencies, and organizations and individuals who have indicated an interest in the EIS process. Copies of the document may also be requested by telephone (1–800-967–3477) or over the Internet via the Yucca Mountain Project website at *http://www.ymp.gov*, under the listing "Environmental Impact Statement."

Copies of references considered in preparation of the Draft EIS are available at the following Public Reading Rooms: University of Nevada—Las Vegas, Nevada; University of Nevada—Reno, Nevada; Beatty Yucca Mountain Science Center, Nevada; and the DOE Headquarters Office in Washington, DC. Addresses of these Public Reading Rooms and of other Public Reading Rooms and libraries where the Draft EIS is available for public review are listed below.

Public Reading Rooms

Inyo County—Contact: Andrew Remus; (760) 878–0447; Inyo County Yucca Mountain Repository Assessment Office; 168 North Edwards Street; Post Office Drawer L; Independence, CA 93526

Oakland Operations Office—Contact: Annette Ross; (510) 637–1762; U. S. Department of Energy Public Reading Room; EIC; 1301 Clay Street, Room 700N; Oakland, CA 94612–5208

National Renewable Energy Laboratory—Contact: Sarah Manion; (303) 275–4709; Public Reading Room; 1617 Cole Boulevard; Golden, CO 80401

Rocky Flats Public Reading Room—Contact: Ann Smith; (303) 469–4435; College Hill Library; 3705 112th Avenue B121; Westminster, CO 80030

Headquarters Office—Contact: Carolyn Lawson; (202) 586–3142; U.S. Department of Energy; Room 1E–190, Forrestal Building; 1000 Independence Avenue, SW; Washington, DC 20585

Atlanta Support Office—Contact: Nancy Mays/Laura Nicholas; (404) 347–2420; Department of Energy; Public Reading Room; 730 Peachtree Street, Suite 876; Atlanta, GA 30308–1212

Southeastern Power Administration—Contact: Joel W. Seymour/Carol M. Franklin; (706) 213–3800/(706) 213–3813; U.S. Department of Energy; Reading Room; Samuel Elbert Building; 2 South Public Square; Elberton, GA 30635–2496

Boise State University Library—Contact: Adrien Taylor; (208) 385–1621; Government Documents; 1910 University Drive; P.O. Box 46; Boise, ID 83707–0046

Idaho Operations Office—Contact: Brent Jacobson/Gail Willmore; (208) 526–1144; Public Reading Room; 1776 Science Center Drive; Idaho Falls, ID 83402

Chicago Operations Office—Contact: John Shuler; (312) 996–2738; Document Department; University of Illinois at Chicago; 801 South Morgan Street; Chicago, IL 60607

Strategic Petroleum Reserve Project Management Office—Contact: Deanna Harvey; (504) 734–4316; U.S. Department of Energy; SPRPMO/SEB

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Reading Room; 850 Commerce Road, East; New Orleans, LA 70123

Lander County—Contact: Tammy Manzini; (775) 964–2447; 610 Main Street; (P.O. Box 10); Austin, NV 89310

Beatty Yucca Mountain Science Center—Contact: Marina Anderson; (775) 553–2130; 100 North E Avenue; Beatty, NV 89003

Lincoln County—Contact: Eve Culverwell; (775) 726–3511; Box 1068 100 Depot Avenue; Caliente, NV 89008

Nevada State Clearinghouse—Contact: Heather Elliot; (775) 684–0209; Department of Administration; 209 Musser Street, Room 200; Carson City, NV 89701

White Pine County—Contact: Debra Kolkman; (775) 289–2033; 959 Campton Street; Ely, NV 89301

Eureka County—Contact: Leonard Fiorenzi; (775) 237–5372; Courthouse Annex; (P.O. Box 714); Eureka, NV 89316

Churchill County—Contact: Alan Kalt; (775) 423–5136; 190 West First Street; Fallon, NV 89046–2478

Esmeralda County—Contact: Tony Cain; (775) 485–3419; Repository Oversight Program; Elliot Street between Franklin and Euclid; P.O. Box 490; Goldfield, NV 89013

Mineral County—Contact: Commissioner Jackie Wells; (775) 945–2484; First & A Streets; (P.O. Box 1600); Hawthorne, NV 89415

Clark County—Contact: Dennis Bechtel; (702) 455–5175; 500 South Grand Central Parkway #3012; (P.O. Box 551751); Las Vegas, NV 89155–1751

Las Vegas, Nevada—Contact: Reference Desk; (702) 895–3409; University of Nevada Las Vegas; James R. Dickinson Library; Government Publications; 4505 Maryland Parkway; Las Vegas, NV 89154–7013

Las Vegas Yucca Mountain Science Center—Contact: Terri Brown; (702) 295–1312; 4101–B Meadows Lane; Las Vegas, NV 89107

Nye County—Contact: Les Bradshaw; (775) 727–7727; c/o Department of Natural Resources and Federal Facilities; 1210 E. Basin Avenue; Pahrump, NV 89048

Pahrump Yucca Mountain Science Center—Contact: Gordon Froman; (775) 727–0896; 1141 South Highway 160; Pahrump NV, 89041

Reno, Nevada—Contact: Kathie Brinkerhoff; (775) 784–6500, x-258; University of Nevada, Reno; The University of Nevada Libraries; Business and Government Information Center M/S 322; 1664 N. Virginia Street; Reno, NV 89557–0044

Albuquerque Operations Office—Contact: Shawna Schwartz; (702) 845–4939; U.S. DOE Contract Reading Room; Kirtland Air Force Base; Pennsylvania and H Street; Building 388; Albuquerque, NM 87116

Fernald Area Office—Contact: Gary Stegner; (513) 648–7480; U.S. Department of Energy; Public Information Room; 7400 Willey Road; Cincinnati, OH 45239

Bartlesville Project Office/National Institute for Petroleum and Energy ResearchÐContact: Josh Stroman; (918) 337–4371; BPO/NIPER Library; U.S. Department of Energy; 220 Virginia Avenue; Bartlesville, OK 74003

Southwestern Power Administration—Contact: Pam Bland; (918) 595–6624; U.S. Department of Energy; Public Reading Room; 1 West 3rd, Suite 1600; Tulsa, OK 74101

Bonneville Power Administration—Contact: Jean Pennington; (503) 230–7334; U.S. Department of Energy; BPA–C–ACS–1; 905 NE 11th Street; Portland, OR 97208

Pittsburgh Energy Technology Center—Contact: Ann C. Dunlap; (412) 892–6167; U.S. Department of Energy; Building 922/M210; Cochrans Mill Road; Pittsburgh, PA 15236–0940

Savannah River Operations Office—Contact: David Darugh; (803) 725–2497; Gregg-Graniteville Library; University of South Carolina—Aiken; 171 University Parkway; Aiken, SC 29801

University of South Carolina—Contact: Lester Duncan; (803) 777–4841; Thomas Cooper Library; Documents/Microforms Department; Green and Sumter Streets; Columbia, SC 29208

Oak Ridge Operations Office—Contact: Amy Rothrock/Teresa Brown; (423) 576-1216/(423) 241–4780; U.S. Department of Energy; Public Reading Room; P.O. Box 2001; American Museum of Science and Energy; 300 S. Tulane Avenue; Oak Ridge, TN 37831

Southern Methodist University—Contact: Stephen Short; (214) 768–2561; Central Union Libraries Fondren Library; Government Information; Airline and McFarland Streets; Dallas, TX 75275–0135

University of Utah—Contact: Walter Jones; (801) 581–8863; Marriott Library Special Collections; 295 South 15th East; Salt Lake City, UT 84112–0860

Richland Operations Center—Contact: Terri Traub; (509) 372–7443; U.S. Department of Energy; Public Reading Room; 2770 University Drive; Room 101L; PO Box 999; Mailstop H2–53; Richland, WA 99352

Issued in Washington, DC, August 5, 1999.

Lake Barrett,

Acting Director, Office of Civilian Radioactive Waste Management.

[FR Doc. 99–20661 Filed 8–12–99; 8:45 am]

BILLING CODE 6450–01–P

6192 **Federal Register** / Vol. 65, No. 26 / Tuesday, February 8, 2000 / Notices

DEPARTMENT OF ENERGY

Comment Period Extension and Additional Public Hearing for Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV

AGENCY: Office of Civilian Radioactive Waste Management, Department of Energy.

ACTION: Notice of comment period extension and additional public hearing.

SUMMARY: On August 13, 1999, the U.S. Department of Energy (DOE) published a Notice of Availability (64 FR 44200) of its Draft Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DOE/EIS–0250–D) and announced a 180-day public comment period ending February 9, 2000. Based on input from the public, DOE is now announcing an additional public hearing in San Bernardino, California. The comment period is being extended to February 28, 2000.

DATES: The additional public hearing will be held on February 22, 2000, from 11:00 a.m. until 2:00 p.m. and from 6:00 p.m. until 9:00 p.m. The comment period for the Draft EIS is extended to February 28, 2000.

ADDRESSES: The additional public hearing will be held at the following location: Radisson Hotel, 295 North E. Street, San Bernardino, CA 92401.

Written comments on the Draft EIS should be directed to: Ms. Wendy R. Dixon, EIS Program Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, NV 89036–0307. Comments may also be transmitted by facsimile to 1–800–967–0739 and should include the following identifier: "Yucca Mountain Draft EIS." Comments may be submitted over the Internet via the Yucca Mountain Project website at *http://www.ymp.gov*, under the listing "Environmental Impact Statement."

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INVITATION TO COMMENT: The public is invited to provide comments on the Draft EIS during the comment period that ends on February 28, 2000. DOE will consider comments received during the comment period in preparation of the Final EIS. Comments received after February 28, 2000 will be considered to the extent practicable.

FOR FURTHER INFORMATION CONTACT: Ms. Wendy R. Dixon, EIS Program Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, NV 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739. Copies of the document may also be requested by telephone (1–800–967–3477) or over the Internet via the Yucca Mountain Project website at *http://www.ymp.gov*, under the listing "Environmental Impact Statement"; the Draft EIS also may be viewed on this website.

Issued in Washington, DC, February 2, 2000.

Ivan Itkin,

Director, Office of Civilian Radioactive Waste Management.

[FR Doc. 00–2714 Filed 2–7–00; 8:45 am]

BILLING CODE 6450–01–P

22540 **Federal Register** / Vol. 66, No. 87 / Friday, May 4, 2001 / Notices

DEPARTMENT OF ENERGY

Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

AGENCY: Department of Energy (DOE).

ACTION: Notice of availability and opportunity for comment.

SUMMARY: The Department of Energy (DOE) announces the availability of a Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (Draft EIS) (DOE/EIS–0250D–S). The Department has prepared this Supplement in accordance with the Nuclear Waste Policy Act of 1982, as amended (NWPA), the National Environmental Policy Act of 1969, as amended (NEPA), the Council on Environmental Quality regulations that implement the procedural provisions of NEPA, and the DOE procedures implementing NEPA. The Council on Environmental Quality NEPA regulations state that an agency may prepare a supplement when it determines that the purposes of NEPA will be furthered by doing so. As anticipated, design enhancements of the proposed repository at Yucca Mountain have evolved since DOE issued the Draft EIS in August 1999. Accordingly, DOE has issued a Supplement to the Draft EIS to address the most recent information on design evolution,

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including enhancements in design details and operating modes, and associated potential environmental impacts. DOE will provide the public an opportunity to comment on the Supplement and conduct hearings on the Supplement, as described below.

DATES: Comments on the Supplement to the Draft EIS will be accepted during a 45-day public comment period, which ends on June 25, 2001. DOE will consider comments submitted after June 25, 2001, to the extent practicable.

ADDRESSES: DOE will conduct public hearings on the Supplement in Amargosa Valley, Las Vegas, and Pahrump, Nevada. Public hearing locations and further details are provided below in this Notice under "Public Hearings and Invitation to Comment."

Written comments and requests for further information on the Supplement to the Draft EIS or the public hearings, and requests for copies of the document and included CD–ROM should be directed to: Dr. Jane Summerson, EIS Document Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, Nevada 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

Written comments via facsimiles should include the following identifier: "Yucca Mountain Supplement to the Draft EIS." Addresses and locations where the Supplement will be available for public review are listed in this Notice under "Availability of the Supplement to the Draft EIS."

Electronic Format: Internet

Written comments on or requests for copies of the document may also be submitted over the Internet via the Yucca Mountain Project website at *http://www.ymp.gov*, under the listing "Environmental Impact Statement."

FOR FURTHER INFORMATION CONTACT: Dr. Jane Summerson, EIS Document Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, Nevada 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

For general information on the DOE NEPA process, contact: Ms. Carol M. Borgstrom, Director, Office of NEPA Policy and Compliance (EH–42), U.S. Department of Energy, 1000 Independence Ave., SW., Washington, DC 20585, Telephone 1–202–586–4600, or leave a message at 1–800–472–2756.

SUPPLEMENTARY INFORMATION: In August 1999, DOE issued the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (Draft EIS), in accordance with the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 *et seq.*), and the Nuclear Waste Policy Act, as amended (42 U.S.C. 10101 *et seq.*). The U.S. Environmental Protection Agency (EPA) issued a Notice of Availability (64 FR 44217) of the Draft EIS on August 13, 1999, initiating a public comment period that ended on February 28, 2000. During the 199-day comment period, DOE held 21 public hearings across the United States. The Draft EIS describes the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The Draft EIS also describes the potential environmental impacts associated with the Proposed Action.

For the Draft EIS, DOE based the analysis on the repository design described in the Viability Assessment of a Repository at Yucca Mountain. The Draft EIS discussed ongoing evaluations that could result in modifications to that design.

As DOE anticipated in the Draft EIS, repository design has continued to evolve. Although the fundamental aspects of the repository design have not changed from those discussed in the Draft EIS, design options and operating modes (ways in which to operate the repository) are being explored to reduce uncertainties and improve long-term repository performance and operational safety and efficiency. DOE has documented the evolution to date of its design efforts in the Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration (YMS&ER), which describes the current design (which the Supplement calls the S&ER flexible design) and a range of possible repository operating modes. The YMS&ER also summarizes current technical information that the Secretary of Energy will use to determine whether to recommend approval of the Yucca Mountain site to the President for development as a repository.

Evaluations are underway to analyze the effect of various operating modes on repository performance. The flexible design discussed in the YMS&ER includes the ability to operate the repository in a range of operating modes that address higher and lower temperatures and associated humidity conditions. The higher-temperature operating mode means that at least a portion of the emplacement drift rock wall would have a maximum temperature above the boiling point of water at the elevation of the repository [96°C (205°F)]. Examples of the lower-temperature operating modes include conditions under which the drift rock wall temperatures would be below the boiling point of water, and conditions under which the waste package surface temperature would not exceed 85°C (185°F). To bound the impact analysis, DOE considered conditions under which the rock wall temperatures would be above the boiling point of water, and conditions under which waste package surface temperatures would not exceed 85°C.

DOE prepared the Supplement to update information presented in the Draft EIS. The Supplement evaluates potential environmental impacts that could occur, based on the design options and range of possible operating modes presented in the YMS&ER. The Supplement compares the impacts associated with the S&ER flexible design to the impacts presented in the Draft EIS.

The basis for the analytical scenarios presented in the Draft EIS was the amount of commercial spent nuclear fuel and its associated thermal output or load that DOE would emplace per unit area of the repository (called areal mass loading). In the Draft EIS, DOE evaluated three thermal load scenarios including high thermal load, a relatively high emplacement density of commercial spent nuclear fuel (85 metric tons of heavy metal (MTHM) per acre), intermediate thermal load (60 MTHM per acre), and low thermal load (25 MTHM per acre). The analytical scenarios described in the Draft EIS were not intended to place a limit on the choices among alternative designs because DOE expected that the repository design would continue to evolve. Rather, DOE selected these scenarios to represent the range of foreseeable design features and operating modes and to ensure that it considered the associated range of potential environmental impacts.

In contrast to focusing on thermal loads, the S&ER flexible design focuses on controlling the temperatures of the rock between the drifts, the waste package surfaces, and the drift walls to meet thermal management goals established for possible repository operating modes. To meet these thermal goals, the S&ER flexible design uses a linear thermal load (heat output per unit length of the emplacement drift) and emplaces waste packages relatively

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closer together than the Draft EIS design. Linear thermal load is expressed in terms of kilowatts per meter.

As with the thermal load analytical scenarios analyzed in the Draft EIS, the range of operating modes under the S&ER flexible design is representative of the range of foreseeable future design features and operating modes. The conservative estimates of the associated potential environmental impacts in the Supplement encompass or bound the potential impacts of foreseeable future repository design evolution.

The Supplement focuses on modifications to the repository design and operating modes addressed in the Draft EIS; it does not analyze aspects of the Proposed Action that have not been modified, such as the transportation of spent nuclear fuel and high-level radioactive waste, or the No-Action Alternative. DOE will address all aspects of the Proposed Action and the No-Action Alternative in the Final EIS. Because repository design has evolved from that considered in the Draft EIS, the Final EIS will evaluate only the S&ER flexible design, including the reasonable range of operating modes, and any enhancements to the flexible design developed as the result of ongoing analyses. DOE invites comments on its intention not to address the Draft EIS design in the Final EIS. DOE will respond to comments on the Draft EIS and on the Supplement in the Final EIS.

Public Hearings and Invitation to Comment

The public is invited to provide oral and written comments on the Supplement to the Draft EIS during the public comment period that ends on June 25, 2001. DOE will consider comments submitted during the comment period in preparation of the Final EIS. Comments submitted after June 25, 2001 will be considered to the extent practicable. DOE will hold public hearings to receive oral and written comments from members of the public at the following times and locations:

May 31, 2001: Longstreet Inn & Casino, Highway 373, Amargosa Valley, Nevada 89020; 5:00 pm–9:00 pm—Poster Session, 6:00 pm–9:00 pm—Hearing

June 5, 2001: Suncoast Hotel & Casino, 9090 Alta Drive, Las Vegas, Nevada 89144; 5:00 pm–9:00 pm—Poster Session, 6:00 pm–9:00 pm—Hearing

June 7, 2001: Bob Ruud Community Center, 150 North Highway #160, Pahrump, Nevada 89048; 5:00 pm–9:00 pm—Poster Session, 6:00 pm–9:00 pm—Hearing

This information will be available on the Yucca Mountain website at (*http://www.ymp.gov*) and on the toll-free information line at 1–800–967–3477.

Each of the public hearings will include a brief session in which an overview of the Supplement will be presented, a general question-and-answer session, and an opportunity to provide comments for the record. Members of the public who plan to present oral comments are asked to register in advance by calling 1–800–967–3477.

Availability of the Supplement to the Draft EIS

Copies of the Supplement are being distributed to Federal, State, and Indian tribal representatives, and other organizations and individuals who have indicated an interest in the EIS process. Copies of this document may be requested by calling 1–800–967–3477 or over the Internet via the Yucca Mountain Project website (*http://www.ymp.gov*). Both the Supplement and the Draft EIS will be available via the Internet on the DOE NEPA website at (*http://tis.eh.doe.gov/nepa*), under the listing DOE NEPA Analyses, or on the Yucca Mountain Project web site listed above. The availability of the Yucca Mountain Science and Engineering Report will be announced in a separate Federal Register Notice. That report will be available or can be requested on the Yucca Mountain Project website (*http://www.ymp.gov*) or by calling 1–800–967–3477.

Copies of references considered in preparation of the Supplement and Draft EIS, including the Yucca Mountain Science and Engineering Report, will be available at the following Public Reading Rooms: University of Nevada—Las Vegas, Nevada; University of NevadaÑ Reno, Nevada; Beatty Yucca Mountain Science Center, Nevada; Pahrump Yucca Mountain Science Center, Nevada; and the DOE Headquarters Office in Washington, D.C. Addresses of these Public Reading Rooms and of other Public Reading Rooms and libraries where the Supplement and the Draft EIS will be available for public review are listed below.

Public Reading Rooms

Inyo County—Contact: Andrew Remus; (760) 878–0447; Inyo County Yucca Mountain Repository Assessment Office; 168 North Edwards St.; Post Office Drawer L; Independence, CA 93526.

Oakland Operations Office—Contact: Laura Martinez; (510) 637–1762; U.S. Department of Energy Public Reading Room; EIC; 1301 Clay St., Room 700N; Oakland, CA 94612–5208.

National Renewable Energy Laboratory—Contact: John Horst; (303) 275–4709; Public Reading Room; 1617 Cole Blvd.; Golden, CO 80401.

Rocky Flats Public Reading Room—Contact: Gary Morrell; (303) 469–4435; College Hill Library; 3705 112th Ave. B121; Westminster, CO 80030.

Headquarters Office—Contact: Carolyn Lawson; (202) 586–3142; U.S. Department of Energy; Room 1E–190, Forrestal Building; 1000 Independence Ave., SW; Washington, DC 20585.

Atlanta Support Office—Contact: Nancy Mays/Laura Nicholas; (404) 347–2420; Department of Energy; Public Reading Room; 730 Peachtree St., Suite 876; Atlanta, GA 30308–1212.

Southeastern Power Administration—Contact: Joel W. Seymour; (706) 213–3800; U.S. Department of Energy; Reading Room; Samuel Elbert Building; 2 South Public Square; Elberton, GA 30635–2496.

Boise State University Library—Contact: Adrien Taylor; (208) 426–1737; Government Documents; 1910 University Dr.; P.O. Box 46; Boise, ID 83707–0046.

Idaho Operations Office—Contact: Brent Jacobson; (208) 526–1144; Public Reading Room; 1776 Science Center Dr.; Idaho Falls, ID 83402.

Chicago Operations Office—Contact: John Shuler; (312) 996–2738; Document Department; University of Illinois at Chicago; 801 South Morgan St.; Chicago, IL 60607.

Strategic Petroleum Reserve Project Management Office—Contact: Deanna Harvey; (504) 734–4316; U.S. Department of Energy; SPRPMO/SEB Reading Room; 850 Commerce Road, East; New Orleans, LA 70123.

Lander County—Contact: Mickey Yarbo; (775) 635–2882; 315 S. Humboldt St.; Battle Mountain, NV 89820.

Beatty Yucca Mountain Science Center—Contact: Marina Anderson; (775) 553–2130; 100 North E Ave.; Beatty, NV 89003.

Lincoln County—Contact: Jason Pitts; (775) 726–3511; Box 1068; 176 Clover St.; Caliente, NV 89008.

Nevada State Clearinghouse—Contact: Heather Elliot; (775) 684–0209; Department of Administration; 209 E. Musser Street, Room 200; Carson City, NV 89701.

White Pine County—Contact: Josie Larson; (775) 289–2033; 959 Campton St.; Ely, NV 89301.

Eureka County—Contact: Leonard Fiorenzi; (775) 237–5372; 701 S. Main St.; (P.O. Box 714); Eureka, NV 89316.

Churchill County—Contact: Alan Kalt; (775) 423–5136; 155 North Taylor St., Suite 182; Fallon, NV 89046–2478.

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Esmeralda County—Contact: George McCorkell; (775) 485–3419; Repository Oversight Program; 233 Crook St.; P.O. Box 295; Goldfield, NV 89316.

Mineral County—Contact: Judy Shankle; (775) 945–2484; First & A Streets; (*Hand Deliverables Only*); (P.O. Box 1600); Hawthorne, NV 89415.

Clark County—Contact: Dennis Bechtel; (702) 455–5178; 500 South Grand Central Parkway #3012; (P.O. Box 551751); Las Vegas, NV 89155–1751.

Las Vegas, Nevada—Contact: Reference Desk; (702) 895–3409; University of Nevada Las Vegas; James R. Dickinson Library; Government Publications; 4505 Maryland Parkway; Las Vegas, NV 89154–7013.

Las Vegas Yucca Mountain Science Center—Contact: Claire Whetsel; (702)295–1312; 4101-B Meadows Lane; Las Vegas, NV 89107.

Nye County—Contact: Les Bradshaw; (775) 727–7727; c/o Department of Natural Resources and Federal Facilities; 1210 E. Basin Ave., Suite 6; Pahrump, NV 89048.

Pahrump Yucca Mountain Science Center—Contact: John Pawlak; (775) 727–0896; 1141 South Highway 160; Pahrump NV, 89041.

Reno, Nevada—Contact: Kathie Brinkerhoff; (775) 784–6500; University of Nevada, Reno; The University of Nevada Libraries; Business and Government Information Center M/S 322; 1664 N. Virginia St.; Reno, NV 89557–0044.

Albuquerque Operations Office—Contact: Dan Berkley; (505) 277–7180; U.S. DOE Contract Reading Room; University of New Mexico; Zimmerman Library; Albuquerque, NM 87131–1466.

Fernald Area Office—Contact: Diane Rayer;(513)648–7480; U.S. Department of Energy; Public Information Room;10995 Hamilton-Cleves Highway M/S 78; Harrison, OH 45030.

Southwestern Power Administration—Contact: Marti Ayres; (918) 595–6609; U.S. Department of Energy; Public Reading Room; 1 West 3rd, Suite 1600; Tulsa, OK 74103.

Bonneville Power Administration—Contact: Bill Zimmerman/Darlene Freestad; (503) 230–7334; U.S. Department of Energy; BPA–C–ACS–1; 905 NE 11th St.; Portland, OR 97232.

Pittsburgh Energy Technology Center—Contact: Ann C. Dunlap; (412) 386–6167; U.S. Department of Energy; Building 922/M210; Cochrans Mill Rd.; Pittsburgh, PA 15236–0940.

Savannah River Operations Office—Contact: Pauline Connell; (803) 725–2497; Gregg-Graniteville Library; University of South Carolina-Aiken; 171 University Parkway; Aiken, SC 29801.

University of South Carolina—Contact: William Suddeth; (803) 777–4841; Thomas Cooper Library; Documents/Microforms Department; Green and Sumter Streets; Columbia, SC 29208.

Oak Ridge Operations Office—Contact: Walter Perry; (865) 241–4780; U.S. Department of Energy; Public Reading Room; P.O. Box 2001; American Museum of Science and Energy; 230 Warehouse Rd.; Oak Ridge, TN 37831.

Southern Methodist University—Contact: Stephen Short; (214) 768–2561; Central Union Libraries Fondren Library; Government Information; Airline and McFarland Streets; Dallas, TX 75275–0135.

University of Utah—Contact: Walter Jones; (801) 581–8863; Marriott Library Special Collections; 295 South 15th East; Salt Lake City, UT 84112–0860.

Richland Operations Center—Contact: Terri Traub; (509) 372–7443; U.S. Department of Energy; Public Reading Room; 2770 University Drive; Room 101L; PO Box 999; Mailstop H2–53; Richland, WA 99352.

Issued in Washington, DC, April 27, 2001.

Lake Barrett,

Acting Director, Office of Civilian Radioactive Waste Management.

[FR Doc. 01–11275 Filed 5–3–01; 8:45 am]

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33534 Federal Register / Vol. 66, No. 121 / Friday, June 22, 2001 / Notices

DEPARTMENT OF ENERGY

Comment Period Extension for Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV

AGENCY: Department of Energy (DOE).

ACTION: Notice of comment period extension.

SUMMARY: On May 4, 2001, the U.S. Department of Energy (DOE) published a Notice of Availability (66 FR 22540) of its Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (Draft EIS) (DOE/EIS–0250D–S) and announced a 45-day public comment period ending June 25, 2001. In response to requests from the public, DOE is extending the comment period to July 6, 2001.

DATES: Comments on the Supplement to the Draft EIS are now due by July 6, 2001. DOE will consider all comments received during the comment period in preparation of the Final EIS. Comments received after July 6, 2001 will be considered to the extent practicable.

ADDRESSES: Written comments and requests for further information on the Supplement to the Draft EIS, and requests for copies of the document (hard copy or CD–ROM) should be directed to: Dr. Jane Summerson, EIS Document Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, Nevada 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

Written comments via facsimiles should include the following identifier: ''Yucca Mountain Supplement to the Draft EIS.''

Written comments on or requests for copies of the document may also be submitted over the internet via the Yucca Mountain Project website at *http://www.ymp.gov*, under the listing ''Environmental Impact Statement.''

FOR FURTHER INFORMATION CONTACT: Dr. Jane Summerson, EIS Document Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, Nevada 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

For general information on the DOE NEPA process, contact: Ms. Carol M. Borgstrom, Director, Office of NEPA Policy and Compliance (EH–42), U.S. Department of Energy, 1000 Independence Avenue, SW., Washington, DC 20585, Telephone 1–202–586–4600, or leave a message at 1–800–472–2756.

Issued in Washington, DC, June 18, 2001.

Ronald Milner,

Chief Operating Officer, Office of Civilian Radioactive Waste Management.

[FR Doc. 01–15682 Filed 6–21–01; 8:45 am]

BILLING CODE 6450–01–U

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DEPARTMENT OF ENERGY

Comment Period for Specific Individuals for the Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV

AGENCY: Department of Energy (DOE).

ACTION: Notice of comment period for specific individuals.

SUMMARY: On May 4, 2001, the U.S. Department of Energy (DOE) published a Notice of Availability (66 FR 22540) of its Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (Draft EIS) (DOE/EIS–0250D–S) and announced a 45-day public comment period ending June 25, 2001. In response to requests from the public, DOE extended the comment period to July 6, 2001 (66 FR 33534). DOE has discovered that some individuals had requested and received a copy of the Draft EIS, but were not sent the Supplement to the Draft EIS. DOE has now distributed the Supplement to those individuals, and will accept comments from those individuals transmitted or postmarked by August 13, 2001.

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DATES: Comments from specific individuals who received a copy of the Supplement with a June 22, 2001 letter from DOE regarding this oversight are now due by August 13, 2001. DOE will consider all comments received from those individuals by that date in preparing the Final EIS. Comments received from those individuals after August 13, 2001 will be considered to the extent practicable.

ADDRESSES: Written comments and requests for further information on the Supplement to the Draft EIS, and requests for copies of the document (hard copy or CD–ROM) should be directed to: Dr. Jane Summerson, EIS Document Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, Nevada 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

Written comments via facsimiles should include the following identifier: ''Yucca Mountain Supplement to the Draft EIS.''

Written comments on or requests for copies of the document may also be submitted over the internet via the Yucca Mountain Project website at http://www.ymp.gov, under the listing ''Environmental Impact Statement.''

FOR FURTHER INFORMATION CONTACT: Dr. Jane Summerson, EIS Document Manager, M/S 010, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, P.O. Box 30307, North Las Vegas, Nevada 89036–0307, Telephone 1–800–967–3477, Facsimile 1–800–967–0739.

For general information on the DOE NEPA process, contact: Ms. Carol M. Borgstrom, Director, Office of NEPA Policy and Compliance (EH–42), U.S. Department of Energy, 1000 Independence Avenue, SW., Washington, DC 20585, Telephone 202–586–4600, or leave a message at 1–800–472–2756.

Issued in Washington, DC, June 25, 2001.

Lake Barrett,

Acting Director, Office of Civilian Radioactive Waste Management.

[FR Doc. 01–16420 Filed 6–28–01; 8:45 am]

BILLING CODE 6450–01–P

Appendix C

Interagency and Intergovernmental Interactions

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LIST OF TABLES

APPENDIX C. INTERAGENCY AND INTERGOVERNMENTAL INTERACTIONS

In the course of producing this environmental impact statement (EIS), the U.S. Department of Energy (DOE) has interacted with a number of governmental agencies and other organizations. These interaction efforts have several purposes, as follows:

- Discuss issues of concern with organizations having an interest in or authority over land that the Proposed Action (to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain) would affect directly, or organizations having other interests that some aspect of the Proposed Action could affect.
- Obtain information pertinent to the environmental impact analysis of the Proposed Action.
- Initiate consultations or permit processes, including providing data to agencies with oversight, review, or approval authority over some aspect of the Proposed Action.
- Provide information relevant to the development of responses to public comments on the Draft EIS and the Supplement to the Draft EIS.

Section C.1 summarizes the interactions. DOE has completed several efforts and will complete all required consultations before publishing the Final EIS. Section C.2 describes interests held by agencies and organizations involved in consultations and other interactions.

C.1 Summary of Activity

Table C-1 lists organizations with which DOE has initiated interaction processes concerning the proposed Yucca Mountain Repository. This table summarizes the authority of or interest of the listed organizations and the status of those interactions.

C.2 Interests of Selected Agencies and Organizations with which DOE Has Held Consultations or Informational Exchanges Regarding the Yucca Mountain Repository Proposal

Regulations that establish a framework for interactions include 40 CFR 1502.25, which provides for consultations with agencies having authority to issue applicable licenses, permits, or approvals, or to protect significant resources, and 10 CFR 1021.341(b), which provides for interagency consultations as necessary or appropriate.

C.2.1 FEDERAL AGENCIES

C.2.1.1 Bureau of Land Management

The Bureau of Land Management has a range of interests potentially affected by the Proposed Action. The Bureau, as a part of the U.S. Department of the Interior:

- Controls a portion of the land that would need to be withdrawn by Congress to accommodate the proposed repository

Table C-1. Organizations with which DOE has initiated interactions (page 1 of 5).

FEDERAL AGENCIES		
Organization	Authority/interest	Interactions
Bureau of Land Management	Controls part of land required for repository. Controls portions of lands in Nevada that transportation corridors cross. Has responsibility for management and use of lands it controls, including management of habitat and species. Has data on topography, habitat, species, and other topics on land it controls.	DOE provided a briefing on the EIS. DOE and BLM held a subsequent meeting to ensure understanding of comments on the Draft EIS and the Supplement to the Draft EIS.
Council on Environmental Quality	Oversees the National Environmental Policy Act process	DOE provided information and NEPA process products, including the Draft EIS and the Supplement to the Draft EIS, to assist CEQ in its oversight responsibility. DOE provided a briefing on the Draft EIS and the Supplement to the Draft EIS, including background information, schedule, and an update on the repository design.
National Marine Fisheries Service	Oversees compliance with Marine Protection Research and Sanctuaries Act and, for some species, with the Endangered Species Act.	DOE informally consulted with the National Marine Fisheries Service on possible effects of barging on threatened and endangered marine species. Endangered Species Act compliance information was requested. Project activities and National Marine Fisheries Service jurisdiction were discussed. DOE has completed activities required for marine species under the Endangered Species Act.
National Park Service	Potential for proposal to affect water supply in Death Valley region. Effect of any water appropriation required for repository, EIS status, and approach to EIS development.	DOE and NPS discussed NPS concerns about use of water for repository construction and operation.
Naval Nuclear Propulsion Program	The Naval Nuclear Propulsion Program is a joint U.S. Navy and DOE organization responsible for management of naval spent nuclear fuel.	DOE has conducted ongoing dialogue and information exchange on the EIS status and the DOE framework.
Nuclear Waste Technical Review Board	Provides technical and scientific expertise in the evaluation of program activities related to site characterization and the packaging, transportation, and disposal of spent nuclear fuel and high-level radioactive waste.	DOE has provided information and work products to the Board, has met with the Board to review aspects of site characterization and the suitability determination, and has received scientific and technical recommendations from the Board. DOE provided a briefing on the Draft EIS and the Supplement to the Draft EIS, including background information, schedule, and an update on the repository design. DOE also provided opportunities for public involvement in some of its interactions with the Board.

Table C-1. Organizations with which DOE has initiated interactions (page 2 of 5).

FEDERAL AGENCIES		
Organization	Authority/interest	Interactions
U.S. Air Force	Controls part of land being considered for withdrawal for repository (on the Nellis Air Force Range) and for one Nevada rail implementing alternative and one heavy-haul truck implementing alternative. Has identified security concerns over potential development of the Nevada rail and heavy-haul truck implementing alternatives that would pass through land it controls.	DOE provided a briefing on the process for this EIS and on the range of issues being analyzed. DOE and USAF personnel held informal meetings to discuss specific issues and update EIS status. The USAF provided a statement of its concerns about certain transportation alternatives DOE is considering.
U.S. Army Corps of Engineers	Has authority over activities that discharge dredge or fill material into waters of the United States.	The two agencies discussed strategies for minimizing impacts and obtaining permits for waters of the United States.
U.S. Department of Agriculture	Responsible for protection of prime farm lands for agriculture in areas potentially affected by the Proposed Action.	Letter exchange resolved issues regarding repository's potential effect on farmlands. Need for additional interaction is uncertain.
U.S. Department of the Interior	Has responsibility for most public lands and natural resources, Indian Affairs, and geological resources, and trust responsibility with respect to American Indians.	DOE and DOI held a meeting to ensure understanding of comments on the Draft EIS and the Supplement to the Draft EIS. Attendees included representatives from the Bureau of Land Management, Fish and Wildlife Service, National Park Service, and the U.S. Geological Survey.
U.S. Department of Transportation	Has regulatory authority over transportation of nuclear and hazardous waste materials, including packaging design, manufacture and use, pickup, carriage, and receipt, and highway route selection.	EIS status briefing has been provided. DOE and DOT have held informal discussions concerning modeling techniques and analytical methods DOE is using in its evaluation of transportation issues.
U.S. Environmental Protection Agency	Has regulatory authority over radiological standards and groundwater protection standards. Mandatory role in review of EIS adequacy.	DOE provided a briefing on its approach to the EIS and on scope and content. EPA described its EIS rating process. The two agencies discussed methods for addressing any EIS comments that EPA might submit. DOE also provided a briefing on the Draft EIS and the Supplement to the Draft EIS.
U.S. Fish and Wildlife Service	Oversees compliance with the Endangered Species Act for some species and compliance with the Fish and Wildlife Coordination Act.	DOE and FWS have held discussions and exchanged species list information pursuant to the Endangered Species Act. DOE submitted a Draft Biological Assessment to the FWS, which issued a Final Biological Opinion that sets forth the measures, terms, and conditions for protection of the desert tortoise.

Table C-1. Organizations with which DOE has initiated interactions (page 3 of 5).

FEDERAL AGENCIES		
Organization	Authority/interest	Interactions
U.S. Nuclear Regulatory Commission	Has licensing authority over spent nuclear fuel and high-level radioactive waste geologic repositories. Is required by NWPA to adopt Yucca Mountain Repository EIS to the extent practicable with the issuance by NRC of any construction authorization and license for a repository. Has regulatory authority over commercial nuclear power plants, storage of spent nuclear fuel at commercial sites, and packaging for transportation of spent nuclear fuel and high-level radioactive waste. Has general authority over possession and transfer of radioactive material.	Discussions have been held on the purpose and need for the action and on the status of the EIS. Numerous interactions related to the potential repository program. An EIS technical exchange was conducted.

STATES AND STATE AGENCIES		
Organization	Authority/interest	Interactions
California Energy Commission	Knowledge of major projects; jurisdiction over aspects of California projects.	DOE provided the Draft EIS distribution list
Nevada State Legislators	Adequacy of Nevada legal structure; passage of legislation	DOE provided an update on the status of the project
State of Nevada Department of Transportation	Has authority over transportation and highways in Nevada.	DOE and NDOT personnel have informally discussed Nevada transportation issues. The State of Nevada received a formal briefing on the Draft EIS and the Supplement to the Draft EIS.
Affected units of local government	Local governments with general jurisdiction over regions or communities that could be affected by implementation of the Proposed Action.	Meetings that include discussions, information exchange, and status briefings, discussion of the OCRWM program, and briefings on the Draft EIS and the Supplement to the Draft EIS and on the process for developing responses to comments on the Draft EIS and the Supplement to the Draft EIS.

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Table C-1. Organizations with which DOE has initiated interactions (page 4 of 5).

Organization	Authority/interest	Interactions
FEDERAL AND STATE AGENCIES CONSULTED JOINTLY		
Advisory Council on Historic Preservation and Nevada State Historic Preservation Officer	Protection and preservation of historic properties and cultural resources of importance to Native Americans and others. Administration of the National Historic Preservation Act and of regulatory requirements supporting that act.	Following discussions among DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Officer, DOE and the Advisory Council on Historic Preservation have entered into a programmatic agreement (DIRS 104558-DOE 1988, all) establishing procedures DOE is to follow during site characterization and during the Secretary of Energy's development of a repository site recommendation. The Advisory Council on Historic Preservation indicated that it would be available to assist DOE in complying with environmental review requirements for historic properties.
LOCAL AGENCIES		
Clark County Desert Conservation Program	Projects potentially affecting desert in Clark County	DOE presented a briefing on Draft EIS studies and measures related to desert tortoise
Clark County Emergency Planning Committee	Projects that could require emergency planning	DOE presented information on the status of EIS
NATIVE AMERICAN ORGANIZATIONS		
National Indian Nuclear Waste Policy Committee	Nuclear waste projects that could affect tribes	DOE presented information on the status of the EIS
Native American Tribes	Have concern for potential consequences of repository development and transportation activities on cultural resources, traditions, and spiritual integrity of the land. Have governmental status. All interactions required for the American Indian Religious Freedom Act, the Native American Graves Protection and Repatriation Act, and the National Historic Preservation Act are being accomplished.	Ongoing discussions on a range of topics at least twice per year. Tribal representatives have prepared and submitted the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all). DOE held formal meetings to present the Draft EIS and the Supplement to the Draft EIS. Formal comments were taken from participants at both meetings.

Table C-1. Organizations with which DOE has initiated interactions (page 5 of 5).

NONGOVERNMENTAL ORGANIZATIONS		
Organization	Authority/interest	Interactions
Advisory Committee on Nuclear Waste	Advisory committee to Nuclear Regulatory Commission on nuclear waste issues	DOE submitted reports on project status, Draft EIS, and Supplement to the Draft EIS, including background information, schedule, update on repository design, and public involvement opportunities.
Commission on Nuclear Projects	Knowledge of DOE activities	Briefing on Draft EIS
Community Advisory Board for the Nevada Test Site	Maintaining awareness of relationships between NTS and the Yucca Mountain repository proposal	Briefings on Draft EIS, Supplement to the Draft EIS, EIS schedule, and project activities.
Community Advisory Board, Idaho National Engineering and Environmental Laboratory	Relationship between Idaho National Engineering and Environmental Laboratory and proposed Yucca Mountain repository	DOE discussed relationship between Idaho National Engineering and Environmental Laboratory and the potential repository
Institute of Nuclear Materials Management	Activities involving nuclear materials	DOE presented information on the Draft EIS status
Interjurisdictional Committee from San Onofre Nuclear Generating Stations	Projects potentially related to San Onofre	DOE made a presentation on transportation issues to the Decisionmakers' Symposium of the Interjurisdictional Committee from San Onofre Nuclear Generating Stations
National Academy of Sciences	Congressionally assigned responsibility to study aspects of repository proposal	DOE presented information on work performed for DOE as part of EIS
National Conference of State Legislators	Knowledge of major projects	Provision of information on potential impacts from proposed repository
Nuclear Energy Institute	Knowledge of DOE activities	DOE answered questions from senior project manager for spent fuel management
Rotary Clubs of Las Vegas	Projects that could affect Las Vegas	DOE provided an update on the status of the project

a. Abbreviations: BLM = Bureau of Land Management; CEQ = Council on Environmental Quality; DOE = U.S. Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; EIS = Environmental Impact Statement; EPA = Environmental Protection Agency; FWS = Fish and Wildlife Service; NDOT = State of Nevada Department of Transportation; NEPA = National Environmental Policy Act; NPS = National Park Service; NRC = Nuclear Regulatory Commission; NTS = Nevada Test Site; NWPA = Nuclear Waste Policy Act; OCRWM = Office of Civilian Radioactive Waste Management; USAF = United States Air Force.

- Controls portions of land in Nevada in the five corridors for a potential branch rail line and along the five potential routes for heavy-haul trucks

- Has responsibility for wild horse and wild burro management areas (Public Law 92-195, as amended, Section 3; 43 CFR Part 2800) and wildlife management areas (43 CFR 24.4) in Nevada that alternative rail corridors and routes for heavy-haul trucks cross

- Has power to grant rights-of-way and easements for transportation routes across lands it controls

The Bureau of Land Management would have a continuing interest in the development of a repository at Yucca Mountain and associated transportation routes in the State of Nevada. Any comments from the Secretary of the Interior on the EIS must be included in the Secretary of Energy's recommendations to the President on the Yucca Mountain site.

Interaction

DOE provided a briefing to the Bureau of Land Management on the status of the Draft EIS, and subsequently met with the Bureau to ensure understanding of comments on the Draft EIS and the Supplement to the Draft EIS.

C.2.1.2 Fish and Wildlife Service

The Fish and Wildlife Service, a bureau of the U.S. Department of the Interior, has a role in the overall evaluation of the impacts from the Proposed Action under consideration in the repository EIS. Under the Endangered Species Act of 1973, as amended, the Fish and Wildlife Service has responsibility to determine if projects such as the proposed Yucca Mountain Repository would have an adverse impact on endangered or threatened species, on species proposed for listing or on designated critical habitat. Any comments from the Secretary of the Interior on the EIS must accompany the Secretary of Energy's recommendation to the President on the Yucca Mountain site.

No endangered or proposed species occur on lands that would be needed for the repository. The desert tortoise is the only threatened species known to exist on this land, which lies at the northern edge of the range for desert tortoises (DIRS 104618-Buchanan 1997, pp. 1 to 4). The repository would not need or impact any critical habitat.

To evaluate the potential for the proposed repository to affect the desert tortoise, DOE and the Fish and Wildlife Service have followed a process that, in summary, includes three steps:

1. DOE submitted a study (biological assessment) containing information on desert tortoise activities and habitat in the vicinity of the proposed project, a description of project activities that could affect the desert tortoise, and the potential for adverse impacts to desert tortoises or habitat. Based on this information, DOE made a determination on whether the project would result in adverse impacts to the species.

2. DOE and the Fish and Wildlife Service met as necessary to discuss details of the potential for interaction between desert tortoises and project activities, and to consider appropriate protective measures DOE could take to reduce the potential for project impact to desert tortoises.

3. The Fish and Wildlife Service issued a biological opinion that states its opinion on whether the proposed project may proceed without causing adverse impacts to the desert tortoise, jeopardizing the continued existence of the species, or resulting in harassment, harm, or death of individual animals. The biological opinion contains protective measures and conditions that DOE would have to implement during construction, operation and monitoring, and closure of the proposed repository to minimize

adverse impacts and the potential for tortoise deaths. The biological opinion is included in the Final EIS as Appendix O.

DOE, which has conducted site characterizations at Yucca Mountain since 1986, and the Fish and Wildlife Service have conducted previous consultation processes that addressed the potential for site characterization activities to affect the desert tortoise. These processes resulted in biological opinions, published in 1990 and 1997, that determined that site characterization activities could proceed without unacceptable harm to the desert tortoise and that the protective measures and conditions stated in the biological opinions should apply to DOE activities. None of the proposed repository land is critical habitat for tortoises. The most recent consultation process on the desert tortoise built on the information gathered and the practices developed in the previous consultations, and on the positive results obtained.

Interaction
Discussions have been held and species list information has been obtained. Discussion topics have included Endangered Species Act compliance issues and agreement on extension of time for completion of the Biological Assessment. DOE submitted a Biological Assessment to the Fish and Wildlife Service. The Fish and Wildlife Service issued a Biological Opinion that contains measures, terms, and conditions for protecting the desert tortoise.

C.2.1.3 Naval Nuclear Propulsion Program

The Naval Nuclear Propulsion Program is a joint U.S. Navy and DOE program responsible for all matters pertaining to naval nuclear propulsion (DIRS 101941-USN 1996, p. 2-2). This program is responsible for the nuclear propulsion plants aboard more than 82 nuclear-powered warships with more than 102 reactors and for nuclear propulsion work performed at four naval shipyards and two private shipyards. It is also responsible for two government-owned, contractor-operated laboratories, two moored training ships, two land-based prototype reactors, and the Expended Core Facility at the Naval Reactors Facility at the Idaho National Engineering and Environmental Laboratory.

The Naval Nuclear Propulsion Program manages naval spent fuel after its withdrawal from nuclear-powered warships and prototype reactors at the Expended Core Facility. The program has conducted studies and performed environmental impact analyses on the management and containerization of naval spent nuclear fuel to prepare it for shipment to the proposed repository or other spent fuel management system (DIRS 101941-USN 1996, all). Information from these studies is relevant to the containerization of other spent nuclear fuel that could be shipped to the proposed repository.

Interaction
Since the beginning of preparations for this EIS, the Naval Nuclear Propulsion Program has participated in quarterly meetings with DOE to discuss information relevant to the emplacement of naval spent nuclear fuel in a monitored geologic repository. Detailed information about naval spent nuclear fuel is classified; therefore, the Naval Nuclear Propulsion Program performed a parallel set of thermal, nuclear, and dose calculations and provided unclassified results to DOE for inclusion in this EIS. In some cases DOE used those results as input parameters for additional analyses. Representatives of the program participated throughout the review process to ensure the accurate presentation of information on naval spent nuclear fuel.

C.2.1.4 National Marine Fisheries Service

The National Marine Fisheries Service exercises protective jurisdiction over aspects of the marine environment, including research activities, marine sanctuaries, and certain species protected by the Endangered Species Act. Potential DOE actions associated with transportation to the repository (for example, barging and construction or modification of bridges and docking facilities) could require interaction with the National Marine Fisheries Service.

Interaction

DOE participated in informal discussions that identified National Marine Fisheries Service jurisdiction relevant to the Yucca Mountain Project and potential project activities of jurisdictional interest to the National Marine Fisheries Service in fulfilling its responsibilities. DOE has completed activities required under the Endangered Species Act for National Marine Fisheries Service jurisdictional species.

C.2.1.5 National Park Service

The National Park Service, which is a bureau of the U.S. Department of the Interior, is responsible for the management and maintenance of the Nation's national parks and monuments. The implementation of the Proposed Action could potentially affect the water supply in Death Valley National Park, which is downgradient from Yucca Mountain. The National Park Service, therefore, would have an interest in any water appropriation granted to DOE for the repository. In addition, the Park Service has expressed its interest in this EIS, its status, and the approach DOE has followed in developing the EIS.

Interaction

DOE and National Park Service representatives held a discussion during which they addressed Park Service concerns about water use for repository construction and operation. The discussion resulted in satisfaction of National Park Service concerns.

C.2.1.6 U.S. Air Force

The U.S. Air Force operates Nellis Air Force Base northeast of Las Vegas, and the Nevada Test and Training Range (formerly called the Nellis Air Force Range), which occupies much of south-central Nevada. The Range is an important facility for training American and Allied combat pilots and crews (DIRS 103472-USAF 1999, pp. 1-1 and 1-3).

A portion of the land being considered for withdrawal for the proposed repository is on the Nellis Range. If the land were withdrawn and development of the proposed repository proceeded, the Air Force would hold a continuing interest in the potential for construction, operation and monitoring, and closure activities at the repository to have consequences for Air Force operations on the adjoining land.

The Nellis Air Force Range is a premier location for training of operational flying units, as well as for conducting developmental and operational testing of advanced weapons systems. The Nellis Range complex consists of extensive air and ground working areas, live ordnance impact areas, and an extensive array of instrumental threat simulators. The Range maintains a heavy volume of testing and training activities on a daily basis. One potential Nevada branch rail line and one potential Nevada heavy-haul truck route that DOE has evaluated in this EIS would pass through the Nellis Range.

Interaction

DOE provided a briefing for U.S. Air Force personnel on the process DOE is following for this EIS and on the range of issues being analyzed. DOE and Air Force personnel have held informal meetings to discuss specific issues.

The U.S. Air Force has communicated to DOE that the transportation of spent nuclear fuel and high-level radioactive waste through the Nellis Range would inevitably lead to the imposition of flight restrictions, and that such restrictions would severely degrade the U.S. Air Force's ability to test existing and evolving weapons systems, or to train U.S. and allied aircrews. In addition, the Air Force maintains that there is no route through the Range that could avoid adversely affecting classified national security activities.

C.2.1.7 U.S. Army Corps of Engineers

The Clean Water Act of 1977 (42 U.S.C. 1251 *et seq.*) gives the U.S. Army Corps of Engineers permitting authority over activities that discharge dredge or fill material into waters of the United States. If DOE activities associated with a repository at Yucca Mountain discharged dredge or fill into any such waters, DOE could need to obtain a permit from the Corps. The construction or modification of rail lines or highways to the repository would also require Section 404 permits if those actions included dredge and fill activities or other activities that would discharge dredge or fill into waters of the United States. DOE has obtained a Section 404 permit for site characterization-related construction activities it might conduct in Coyote Wash or its tributaries or in Fortymile Wash.

Interaction

DOE and the Corps of Engineers have discussed strategies for minimizing impacts to any waters of the United States and have reviewed procedures for obtaining permits in the event that DOE activities could result in discharge of dredge or fill to the waters of the United States.

C.2.1.8 U.S. Department of Agriculture

The U.S. Department of Agriculture has the responsibility to ensure that the potential for Federal programs to contribute to unnecessary and irreversible conversion of farmlands to nonagricultural uses is kept to a minimum. Proposed Federal projects must obtain concurrence from the Natural Resource Conservation Service of the Department of Agriculture that potential activities would not have unacceptable effects on farmlands (7 U.S.C. 4201 *et seq.*).

Interaction

DOE has submitted documentation to the Department of Agriculture on potential consequences of the Proposed Action for farmlands. The Department of Agriculture has reviewed the documentation and the two agencies have agreed that a repository at Yucca Mountain would not affect farmlands.

C.2.1.9 U.S. Department of the Interior

The U.S. Department of the Interior has responsibility for most nationally owned public lands and natural resources. Department of the Interior activities potentially affected by the Proposed Action include managing lands and resources, conducting scientific research and investigations, developing resources, and carrying out trust responsibilities of the U.S. Government with respect to American Indians. The Department of the Interior oversees various bureaus with jurisdictional responsibilities or interests affected by Yucca Mountain: The Bureau of Indian Affairs, the Bureau of Land Management, the National Park Service, the Office of Surface Mining, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. In addition to meeting with the Department of the Interior itself, DOE has contacted several of the bureaus separately regarding Yucca Mountain.

Interaction

DOE met jointly with the Department of the Interior and several of its bureaus (Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, U.S. Geological Survey) to ensure understanding of comments made on the Draft EIS and the Supplement to the Draft EIS.

C.2.1.10 U.S. Department of Transportation

The U.S. Department of Transportation has the authority to regulate several aspects of the transportation of spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository. The general authority of the Department of Transportation to regulate carriers and shippers of hazardous materials includes packaging procedures and practices, shipping of hazardous materials, routing, carrier operations, equipment, shipping container construction, and receipt of hazardous materials (49 U.S.C. 1801; 49 CFR Parts 171 through 180).

Interaction

DOE and the Department of Transportation have exchanged letters and informal communications on topics pertaining to the proposed Yucca Mountain Project that are within the Department of Transportation's regulatory interest. DOE and the Department of Transportation have held informal discussions on the modeling techniques and analytical methods DOE used in its evaluation of transportation issues.

C.2.1.11 U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency has two primary responsibilities in relation to the proposed Yucca Mountain Repository. It is responsible for promulgating regulations that set radiological protection standards for media that would be affected if radionuclides were to escape the confinement of the repository. In addition, the Agency oversees the National Environmental Policy Act process for Federal EISs. Council on Environmental Quality regulations implementing the National Environmental Policy Act specify procedures that agencies must follow and actions that agencies must take in preparing EISs. Depending on the level of concern that the Agency might have with environmental aspects of the Yucca Mountain Project Draft EIS, it can initiate a consultation between DOE and the Council on Environmental Quality. Under the Nuclear Waste Policy Act, as amended (NWPA), the Secretary of Energy's recommendation to the President must include both a Final EIS and the Environmental Protection Agency's comments on the EIS.

Interaction

DOE and the Environmental Protection Agency held a meeting at which DOE provided a briefing on its approach to the EIS and its scope and content. At that meeting, the Environmental Protection Agency described its EIS rating process, and personnel from the two agencies discussed methods for addressing EIS comments that the Agency submitted on the Draft EIS.

In addition, DOE provided a briefing to the Environmental Protection Agency on the Draft EIS and the Supplement to the Draft EIS. The briefing included information on schedule, update of the repository design, and opportunities provided for public involvement during the EIS preparation process.

C.2.1.12 U.S. Nuclear Regulatory Commission

The Nuclear Waste Policy Act, as amended (42 U.S.C. 10101 *et seq.*), establishes a multistep procedure for reviews and decisions on the proposal to construct, operate and monitor, and close a geologic repository at Yucca Mountain. The final steps in this procedure require DOE to make an application to the Nuclear Regulatory Commission for authorization to construct a repository at Yucca Mountain and the Commission to consider this information and make a final decision within 3 years on whether to approve the application. The NWPA directs the Commission to adopt this EIS to the extent practicable in support of its decisionmaking process. Any Nuclear Regulatory Commission comment on this EIS must accompany the Secretary of Energy's recommendation to the President.

The Nuclear Regulatory Commission also has authority under the Atomic Energy Act of 1954, as amended, to regulate persons authorized to own, possess, or transfer radiological materials. In addition, the Commission regulates transportation packaging, transportation operations, and the design, manufacture, and use of shipping containers for radiological materials with levels of radioactivity greater than Department of Transportation Type A materials. Determination as to whether radiological materials are Type A or greater are made in accordance with a procedure set forth in 49 CFR 173.431.

Interaction

Discussions have been held on the purpose and need for the Proposed Action and on the status of the EIS. The regulatory context of the EIS has been reviewed. Additional discussions have been related to the repository program in general or to specific informational items. An EIS technical exchange was conducted. Further interactions with the Nuclear Regulatory Commission will include those necessary to process any application to construct a repository at Yucca Mountain and to ensure a common understanding of technical information and issues.

C.2.2 STATE AND STATE AGENCIES

C.2.2.1 State of Nevada

If DOE receives authorization to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain, DOE would need to obtain a range of permits and approvals from the State of Nevada. DOE would need to coordinate application processing activities with the State to complete the permitting processes. DOE could require permits or approvals such as the following:

- An operating permit for control of gaseous, liquid, and particulate emissions associated with construction and operation
- A public water system permit and a water system operating permit for provision of potable water
- A general permit for storm-water discharge
- A National Pollutant Discharge Elimination System permit for point source discharges to waters of the State
- A hazardous materials storage permit to store, dispense, use, or handle hazardous materials
- A permit for a sanitary and sewage collection system
- A solid waste disposal permit
- Other miscellaneous permits and approvals

DOE required similar permits and approvals from the State of Nevada to conduct site characterization activities at Yucca Mountain. DOE and the State coordinated on a range of activities, including an operating permit for surface disturbances and point source emissions, an Underground Injection Control Permit and a Public Water System Permit, a general discharge permit for effluent discharges to the ground surface, a permit for the use of groundwater, a permit from the State Fire Marshal for the storage of flammable materials, and a permit for operation of a septic system. DOE could apply for additional or expanded authority under the existing permits, where needed, if provisions for expansion became applicable. DOE or its contractors could also need to coordinate transportation activities, highway uses, and transportation facility construction and maintenance activities with the Nevada Department of Transportation, including procedures applicable to the construction and operation of roadways.

Interaction

The State of Nevada received a formal briefing on the Draft EIS after its publication. DOE and Nevada Department of Transportation personnel have had informational discussions on Nevada transportation issues.

C.2.3 FEDERAL AND STATE AGENCIES CONSULTED JOINTLY

C.2.3.1 Advisory Council on Historic Preservation and Nevada State Historic Preservation Officer

In the mid- to late-1980s, DOE, the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation discussed the development of a Programmatic Agreement to address DOE responsibilities under Sections 106 and 110 of the National Historic Preservation Act and the Council's implementing regulations. These discussions led to a Programmatic Agreement between DOE and the Advisory Council on Historic Preservation (DIRS 104558-DOE 1988, all) that records stipulations and terms to resolve potential adverse effects of DOE activities on historic properties at Yucca Mountain. The activities covered by the Agreement include site characterization of the Yucca Mountain site under the NWPA and the DOE recommendation to the President on whether or not to develop a repository, informed by a final EIS prepared pursuant to the National Environmental Policy Act and the NWPA.

Although not a formal signatory, the Nevada State Historic Preservation Officer has the right at any time, on request, to participate in monitoring DOE compliance with the Programmatic Agreement. In addition, DOE must provide opportunities for consultations with the Advisory Council on Historic Preservation, the Nevada State Historic Preservation Officer, and Native American tribes as appropriate throughout the process of implementing the Agreement. DOE submits an annual report to the Advisory Council and the Nevada State Historic Preservation Officer describing the activities it conducts each year to implement the stipulations of the Programmatic Agreement. This report includes a description of DOE coordinations and consultations with Federal and State agencies and Native American Tribes on historic and culturally significant properties at Yucca Mountain.

DOE will continue to seek input from the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation, and will interact appropriately to meet the reporting and other stipulations of the Programmatic Agreement.

Interaction

DOE has submitted annual reports to the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation and has provided opportunities for consultations with agencies and Native American Tribes as appropriate in accordance with the terms of the Programmatic Agreement.

C.2.4 LOCAL AGENCIES

C.2.4.1 Affected Units of Local Government

As defined by the NWPA, the affected units of local government are local governments (counties) with jurisdiction over the site of a repository. At the discretion of the Secretary of Energy, affected units of local government can also include other local governments that are contiguous to the unit that has jurisdiction. Concerns of the affected units of local government range from socioeconomic impacts to potential consequences of transportation activities. Nye County, Nevada, has jurisdiction over the repository site and is one of the affected units of local government. The Secretary has included Clark, Lincoln, Esmeralda, Mineral, Churchill, Lander, Eureka, and White Pine Counties in Nevada and Inyo County in California as affected units of local government. DOE has also sought input on the Proposed Action from Elko County, Nevada, which is not contiguous to Nye County, but which could be affected by transportation activities associated with the Proposed Action.

DOE has offered local governments the opportunity to submit documents providing perspectives of issues associated with the EIS. At Draft EIS publication, Nye County had prepared such a document.

In addition, other documents related to the Yucca Mountain region have been prepared in the past by several local government units including Clark, Lincoln, and White Pine Counties.

Interaction

DOE has held formal meetings twice a year with the affected units of local government. These meetings have included discussions and status briefings on a range of issues of interest to local governments, including a discussion of the Yucca Mountain program, briefings on the Draft EIS, information exchanges, consultation on permitting processes, and the process for developing responses to comments on the Draft EIS and the Supplement to the Draft EIS. DOE has also held numerous informal meetings with local government representatives. Documents have been received from units of local government.

C.2.5 NATIVE AMERICAN TRIBES

Many tribes have historically used the area being considered for the proposed Yucca Mountain Repository, as well as nearby lands (DIRS 102043-AIWS 1998, p. 2-1). The region around the site holds a range of cultural resources and animal and plant resources. Native American tribes have concerns about the protection of cultural resources and traditions and the spiritual integrity of the land. Tribal concerns extend to the propriety of the Proposed Action, the scope of the EIS, and opportunities to participate in the EIS process, as well as issues of environmental justice and the potential for transportation impacts (DIRS 102043-AIWS 1998, pp. 2-2 to 2-26, and 4-1 to 4-12). Potential rail and legal-weight truck routes would follow existing rail lines and highways, respectively. The legal-weight truck route would pass through the Moapa Indian Reservation and the potential rail line would pass near the Reservation. Potential routes for legal-weight and heavy-haul trucks would follow existing highways, and would pass through the Las Vegas Paiute Indian Reservation.

DOE Order 1230.2 recognizes that Native American tribal governments have a special and unique legal and political relationship with the Government of the United States, as defined by history, treaties, statutes, court decisions, and the U.S. Constitution. DOE recognizes and commits to a government-to-government relationship with Native American tribal governments. DOE recognizes tribal governments as sovereign entities with, in most cases, primary authority and responsibility for Native American territory. DOE recognizes that a trust relationship derives from the historic relationship between the Federal Government and Native American tribes as expressed in certain treaties and Federal law. DOE has and will consult with tribal governments to ensure that tribal rights and concerns are considered before taking actions, making decisions, or implementing programs that could affect tribes. These interactions ensure compliance with provisions of the American Indian Religious Freedom Act (42 U.S.C. 1996 *et seq.*), the Native American Graves Protection and Repatriation Act (25 U.S.C. 3001 *et seq.*), DOE Order 1230.2 (*American Indian Tribal Government Policy*), Executive Order 13007 (*Sacred Sites*), Executive Order 13084 (*Consultation and Coordination with Indian Tribal Governments*), and the National Historic Preservation Act (16 U.S.C. 470f).

Interaction

The Native American Interaction Program was formally begun in 1987. Representatives from the Consolidated Group of Tribes and Organizations have met in large group meetings twice yearly with DOE on a range of cultural and other technical concerns. Additionally, specialized Native American subgroups have been periodically convened to interact with DOE on specific tasks including ethnobotany, review of artifact collections, field archaeological site monitoring, and the EIS process.

The Consolidated Group of Tribes and Organizations consists of the following:

- Southern Paiute
  - Kaibab Paiute Tribe, Arizona
  - Paiute Indian Tribes of Utah
  - Moapa Band of Paiutes, Nevada
  - Las Vegas Paiute Tribe, Nevada
  - Pahrump Paiute Tribe, Nevada
  - Chemehuevi Paiute Tribe, California
  - Colorado River Indian Tribes, Arizona
- Western Shoshone
  - Duckwater Shoshone Tribe, Nevada
  - Ely Shoshone Tribe, Nevada
  - Yomba Shoshone Tribe, Nevada
  - Timbisha Shoshone Tribe, California
- Owens Valley Paiute and Shoshone
  - Benton Paiute Tribe, California
  - Bishop Paiute Tribe, California
  - Big Pine Paiute Tribe, California
  - Lone Pine Paiute Tribe, California
  - Fort Independence Paiute Tribe, California
- Other Official Native American Organizations
  - Las Vegas Indian Center, Nevada

Tribal representatives have prepared and submitted the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all). This document discusses site characterization at Yucca Mountain and the Proposed Action in the context of Native American culture, concerns, and views and beliefs concerning the surrounding region. It has been used as a resource in the preparation of the EIS; excerpts are presented in Chapter 4, Section 4.1.13.4, to reflect a Native American point of view. The issues discussed ranged from traditional resources to concerns related to the potential repository.

C.3 Interests of Selected Government Organizations Having Oversight of DOE Activities Related to the Yucca Mountain Repository

C.3.1 COUNCIL ON ENVIRONMENTAL QUALITY

Congress established the Council on Environmental Quality within the Executive Office of the President as part of the National Environmental Policy Act of 1969. In enacting that Act, Congress recognized that nearly all Federal activities affect the environment in some way, and mandated that before Federal agencies take action, they must consider the effects of their actions on the quality of the human environment. It is primarily responsible for coordinating Federal environmental efforts and works closely with agencies and other White House offices in the development of environmental policies and initiatives. One of the Council's primary tasks is overseeing Federal agencies' implementation of the environmental impact assessment process.

Interaction
DOE has provided information and documents, including the Draft EIS and the Supplement to the Draft EIS, to the Council on Environmental Quality. DOE provided a briefing on the Draft EIS and the Supplement to the Draft EIS, including information on schedule, update of the repository design, and opportunities provided for public involvement during the EIS preparation process. Under the NWPA, the Council has a responsibility to provide its comments on the EIS to the President if the Secretary of Energy recommends approval of the Yucca Mountain site.

C.3.2 NUCLEAR WASTE TECHNICAL REVIEW BOARD

The Nuclear Waste Policy Amendments Act of 1987 created the 11-member Nuclear Waste Technical Review Board to evaluate DOE scientific and technical activities related to the management and disposal of the Nation's commercial spent nuclear fuel. The Board's primary responsibility is to evaluate (1) the site characterization phase of the Yucca Mountain Project and the activities associated with determining whether the Yucca Mountain site is suitable for further development as a geologic repository, and (2) the packaging and transportation of spent nuclear fuel and high-level radioactive waste.

The mandate of the Board is to evaluate the scientific and technical work DOE is performing in its commercial nuclear waste disposal program. The Board makes scientific and technical recommendations to DOE to ensure a technically defensible site suitability determination and License Application, and advises DOE on the organization and integration of scientific and technical work pertinent to the Yucca Mountain site.

Interaction
DOE has provided information and work products to the Board, has met with the Board to review aspects of site characterization and the site suitability determination, and has received scientific and technical recommendations from the Board. Many of these interactions were open to the public. DOE provided a briefing on the Supplement to the Draft EIS, including information on schedule, update of the repository design, and opportunities provided for public involvement during the EIS preparation process.

C.4 Requests for Cooperating Agency Status

This EIS addresses a range of potential activities that are of potential concern to other agencies and to Native Americans. Governmental agencies and Native American tribes participated in the EIS process by submitting scoping comments and may submit comments on this Draft EIS. Representatives of Native American tribes have submitted a document that provides their perspective on the Proposed Action. Moreover, DOE has invited local governments in Nevada to submit reference documents providing information on issues of concern.

DOE is the lead agency for this EIS. The lead agency may request any other Federal agency that has jurisdiction by law or special expertise regarding any environmental impact involved in a proposal (or a reasonable alternative) to be a cooperating agency for an EIS (40 CFR 1501.6 and 1508.5). The regulations also allow another Federal agency to request that the lead agency designate it as a cooperating agency. Finally, the regulations allow state or local agencies of similar qualifications or, when the effects are on a reservation, a Native American Tribe, by agreement with the lead agency to become a cooperating agency (40 CFR 1508.5).

If the lead agency designates a cooperating agency, the lead agency's duties toward the cooperating agency include the following:

- Requesting early participation in the National Environmental Policy Act (that is, EIS) process

- Using any environmental analysis or proposal provided by a cooperating agency with legal jurisdiction or special expertise to the greatest extent possible consistent with its responsibilities as a lead agency
- Meeting with a cooperating agency when the cooperating agency requests environmental analyses including portions of the EIS for which the cooperating agency has special expertise
- If the lead agency requests, making staff support available
- Using its own funds, except the lead agency is to fund major activities or analyses it requests to the extent available

Several agencies, tribes, or tribal organizations have either requested cooperating agency status for this EIS, made comparable proposals for participation, or stated positions in regard to the extent of their participation. Table C-2 summarizes agency requests, proposals, and position statements together with the DOE responses, if appropriate. DOE did not designate any cooperating agencies for this EIS process.

Table C-2. History of requests for cooperating status and similar proposals (page 1 of 4).

Agency	Request/statement/offer	Date	DOE response	Date
U.S. Department of the Navy	Request for cooperating agency status (DIRS 104637-Guida 1995, all)	May 23, 1995	DOE can draw on existing information from Navy participation in other EISs. DOE will conduct close consultations to ensure accuracy of information used. DOE declines cooperating agency status (DIRS 104625-Dixon 1995, all).	July 10, 1995
U.S. Department of the Interior, National Park Service	Request for cooperating agency status (DIRS 104643-Martin 1995, all)	September 21, 1995	DOE prefers to address NPS comments or issues related to the Death Valley National Park through close consultations between the two agencies. DOE declines cooperating agency status (DIRS 104627-Dixon 1995, all).	November 11, 1995
Nye County	Request for cooperating agency status (DIRS 104645-McRae 1995, all) (DIRS 104614-Bradshaw 1995, all) (DIRS 104630-YMP 1997, all) (DIRS 104615-Bradshaw 1998, all)	August 15, 1995 October 4, 1995 December 5, 1995 July 30, 1998	DOE expresses appreciation for the County's interest and desire to participate, commits to active consultations with Nye County and other entities on selected issues during EIS development, outlines general elements of consultation and coordination contemplated by DOE. DOE declines cooperating agency status (DIRS 104604-Barnes 1995, all) (DIRS 104605-Barnes 1995, all) (DIRS 104608-Barrett 1998, all).	November 21, 1995 December 1, 1995 September 24, 1998
Churchill County	Request for cooperating agency status (DIRS 104653-Regan 1995, all)	May 30, 1995	DOE does not foresee the need to establish formal MOUs to govern Churchill County's or other parties' participation in the NEPA process for the Repository EIS. CEQ and DOE regulations provide sufficient guidance for participation of all affected units of local government and members of the public. DOE describes steps being taken to ensure all interested and potentially affected organizations and individuals have early and equal opportunity to participate in EIS development. DOE declines cooperating agency status (DIRS 104606-Barnes 1995, all).	July 21, 1995

Table C-2. History of requests for cooperating status and similar proposals (page 2 of 4).

Agency	Request/statement/offer	Date	DOE response	Date
Lincoln County	Proposal for a cooperative agreement with DOE in assessing the continued development of rail and highway route options to the Yucca Mountain site (DIRS 104656-Wright 1996, all).	April 22, 1996	DOE expresses appreciation for the County's desire to participate in DOE transportation planning activities, but indicates that, because much of the planning will be done to support the EIS, a cooperative agreement would be unnecessary. DOE identifies active consultation and coordination as an objective of the EIS process (DIRS 104610-Benson 1996, all).	August 2, 1996
Nuclear Regulatory Commission	NRC does not intend to participate as a cooperating agency (DIRS 104640-Holonich 1995, all)	March 1, 1995	DOE sent no response to this letter.	NA
Nuclear Regulatory Commission	NRC sent a letter (July 7, 1997) to the Navy. The NRC letter responded to a Navy transmission to the NRC of information on naval spent nuclear fuel. The information had been prepared for EIS use. In its letter, the NRC indicated that it would evaluate the information as part of prelicensing consultations with DOE on waste form issues but that, because NRC is required to review and adopt any EIS submitted as part of a DOE License Application, including information on naval SNF, NRC staff does not intend to formally review and comment on the Navy data. NRC sent DOE a copy of its response to the Navy (DIRS 104654-Stablein 1997, all).	August 22, 1996	NA	NA

Table C-2. History of requests or cooperating status and similar proposals (page 3 of 4).

Agency	Request/statement/offer	Date	DOE response	Date
U.S. Department of Air Force	Letter from USAF to the State of Nevada, stating that DOE has no obligation to consult with USAF regarding the transportation options DOE elects to evaluate as a result of NEPA public scoping comments, including the Caliente-Chalk Mountain heavy-haul route through Nellis Air Force Range. USAF acknowledged its close interaction with YMP and its intent to "continue this close relationship" (DIRS 104632-Esmond 1997, all).	September 4, 1997	NA	NA
Council of Energy Resources Tribes	Concept paper for Native American participation in the production of the YMP EIS (DIRS 104622-Burnell 1996, all).	June 19, 1996	DOE expressed thanks for the concept paper, described the status of the EIS (deferred during Fiscal Year 1996), committed to consideration of comments expressed in the concept paper along with all other comments received during the public scoping process. DOE stated that it would prepare a scoping comment summary and make the summary publicly available, indicated its active consideration of various approaches to consultations with other agencies and Native American tribes, including possible preparation of an EIS-referenceable document (DIRS 104629-Dixon 1996, all).	July 26, 1995
Advisory Council on Historic Preservation	Expressed thanks for DOE invitation to participate in the EIS process. Indicated desire to assist with development of the EIS and availability to assist DOE in complying with environmental review requirements; expressed intent to provide comments on the draft EIS (DIRS 104652-Nissley 1995, all).	October 12, 1995	DOE did not prepare a response to this formal scoping comment.	NA

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Table C-2. History of requests for cooperating status and similar proposals (page 4 of 4).

Agency	Request/statement/offer	Date	DOE response	Date
Timbisha Shoshone Tribe of Death Valley, California	Letter to President Clinton expressing opposition to YMP; enclosed a Tribal Resolution condemning the siting of YMP; requested active involvement/consultation at a government-to-government level (DIRS 104613-Boland 1996, all).	August 14, 1996	DOE acknowledged expressed concerns and Tribal Resolution; identified ongoing Native American Interaction Program as vehicle to promote consultations and protection of cultural resources in YMP area; stated that comments from tribal governments were actively solicited during scoping period and Timbisha Shoshone will be afforded opportunity to comment on Draft EIS following its publication (DIRS 104607-Barnes 1996, all).	November 12, 1996
National Congress of American Indians	Letter expressed thanks to DOE (Secretary O'Leary) for invitation to meeting of public and private officials to exchange views on DOE management of SNF and radioactive waste, described NCAI as an organization, described Federal Government's fiduciary duty to tribes as sovereign nations, discussed lack of "affected status" for tribes under the NWPA, state Secretary O'Leary's three commitments to Federally recognized tribes in the Yucca Mountain area during the last year, including inclusion in future Yucca Mountain consultations, requested that DOE and Congress mandate a participatory role for tribal governments as part of any proposals to change the NWPA (DIRS 104633-Gaiashkibos 1995, all).	March 1, 1995	NA	NA

a. Abbreviations: CEQ = Council on Environmental Quality; MOU = Memorandum of Understanding; NA = not applicable; CAI = National Congress of American Indians; NEPA = National Environmental Policy Act; NPS = National Park Service; NRC = U.S. Nuclear Regulatory Commission; NWPA = Nuclear Waste Policy Act; SNF = spent nuclear fuel; USAF = U.S. Air Force; YMP = Yucca Mountain Project.

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104604 Barnes 1995 Barnes, W.A. 1995. "Nye County's Request for Cooperating Agency Designation." Letter from W.A. Barnes (DOE/YMSCO) to The Honorable C. McRae, November 21, 1995, MFR:AMESH:WRD-4730, with enclosure. ACC: MOL.19960424.0182.

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104610 Benson 1996 Benson, A.B. 1996. Response to Letter Dated April 22, 1996 from The Honorable E.E. Wright, Regarding the Department's Preliminary Transportation Strategies. Letter from A.B. Benson (DOE/YMSCO) to E.E. Wright (Lincoln County Commissioner), August 2, 1996. MFR:OPA:ABB-2312. ACC: MOL.19961115.0045.

104613	Boland 1996	Boland, R.F. 1996. "Yucca Mountain High Level Nuclear Waste Depository Siting in Nevada Threatens Native American Cultural Resources and Adversely Affects Public Health and Safety." Letter from R.F. Boland (The Timbisha Shoshone) to W.J. Clinton (President of the United States), August 14, 1996. ACC: HQO.19961112.0018.
104614	Bradshaw 1995	Bradshaw, L.W. 1995. Chairman of Nye County Commission's August 15th Letter Requesting that Nye County be Designated a Cooperating Agency in the Preparation of the Environmental Impact Statement. Letter from L.W. Bradshaw (Nuclear Waste Repository Project Office) to Dr. D. Dreyfus (DOE, OCRWM), October 4, 1995, EIS:AR-PR-55006. ACC: MOL.19990319.0217.
104615	Bradshaw 1998	Bradshaw, L.W. 1998. "Request for Cooperating Agency Status in the Preparation of the Yucca Mountain (YM) Environmental Impact Statement (EIS)." Letter from L.W. Bradshaw (Nye County Department of Natural Resources & Federal Facilities) to L. Barrett (DOE/OCRWM), July 30, 1998. ACC: MOL.19980903.0847.
104618	Buchanan 1997	Buchanan, C.C. 1997. "Final Biological Opinion for Reinitiation of Formal Consultation for Yucca Mountain Site Characterization Studies." Letter from C.C. Buchanan (Department of the Interior) to W. Dixon (DOE/YMSCO), July 23, 1997, File No. 1-5-96-F-307R. ACC: MOL.19980302.0368.
104622	Burnell 1996	Burnell, J.R. 1996. Involving Native Americans in the Development of the Environmental Impact Statement for the Yucca Mountain Project. Letter from J.R. Burnell (Council of Energy Resource Tribes) to J. Chirieleison (DOE/OCRWM), June 19, 1996, with enclosure. ACC: MOL.19961002.0379; MOL.19961002.0380.
104625	Dixon 1995	Dixon, W.R. 1995. "Proposal to Participate as a Cooperating Agency in the Yucca Mountain Site Characterization Office's (YMSCO) Preparation of an Environmental Impact Statement (EIS) for a Potential Repository at Yucca Mountain, Nevada." Letter from W.R. Dixon (DOE/YMSCO) to R.A. Guida (Regulatory Affairs Office of Naval Reactors) July 10, 1995. ACC: MOL.19990610.0298.
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104629	Dixon 1996	Dixon, W.R. 1996. Native American Participation in the Production of an Environmental Impact Statement (EIS) for the Yucca Mountain Repository. Letter from W.R. Dixon (DOE/YMSCO) to J.R. Burnell (Council of Energy Resource Tribes), July 26, 1996. ACC: MOL.19961015.0306.

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104632	Esmond 1997	Esmond, M.R. 1997. "Chalk Mountain Heavy Haul Route." Letter from M.R. Esmond (Department of the Air Force) to R.R. Loux (NWPO), September 4, 1997. ACC: MOL.19971124.0417.
104633	Gaiashkibos 1995	Gaiashkibos 1995. Participatory Role for Tribal Governments in Any Proposals to Change DOE's Spent Nuclear Fuel and Radioactive Waste Management Strategies. Letter from Gaiashkibos (NCAI) to H. O'Leary (DOE), March 1, 1995. ACC: MOL.19990610.0304.
104637	Guida 1995	Guida, R.A. 1995. "Comments on Notice of Intent for Repository EIS." Memorandum from R.A. Guida (DOE) to L. Barrett (DOE/OCRWM), May 23, 1995, with attachment. ACC: HQO.19950712.0020.
104640	Holonich 1995	Holonich, J.J. 1995. "Identification of Lead Contact in Nuclear Regulatory Commission's Review and Comment of U.S. Department of Energy's Draft Environmental Impact Statement." Letter from J.J. Holonich (NRC) to R.A. Milner (DOE/OCRWM), March 1, 1995, with enclosure. ACC: MOL.19990610.0301.
104643	Martin 1995	Martin, R.H. 1995. Death Valley National Park Participation in Scoping for the Development of an Environmental Impact Statement (EIS) and as a Cooperating Agency in the Development of the Draft EIS. Letter from R.H. Martin (DOI) to W.R. Dixon (DOE/YMSCO), September 21, 1995, L7619 (Yucca Mtn). ACC: MOL.19960312.0266.
104645	McRae 1995	McRae, C. 1995. "Cooperating Agency Designation for Nye County in the Preparation of the Yucca Mountain Environmental Impact Statement (EIS)." Letter from C. McRae (Nye County Board of Commissioners) to Dr. D. Dreyfus (DOE/OCRWM), August 15, 1995, with attachment. ACC: MOL.19960321.0319.
104652	Nissley 1995	Nissley, C. 1995. Advisory Council on Historic Preservation Participation in the Preparation of an Environmental Impact Statement (EIS) for a Geologic Repository at Yucca Mountain. Letter from C. Nissley (Advisory Council on Historic Preservation) to W. Dixon (DOE/YMSCO), October 12, 1995. ACC: MOL.19990319.0206.
104653	Regan 1995	Regan, J. 1995. Revised Version of the Memorandum of Understanding (MOU) Between Churchill County and the U.S. Department of Energy (DOE) Regarding Responsibilities and Roles. Letter from J. Regan (Churchill County Commissioners) to M. Powell (DOE), May 30, 1995, with enclosure. ACC: MOL.19990610.0299.

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104630	YMP 1997	YMP (Yucca Mountain Site Characterization Project) 1997. Summary of Public Scoping Comments Related to the Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19970731.0515.

Appendix D

Distribution List

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APPENDIX D. DISTRIBUTION LIST

The U.S. Department of Energy (DOE) is providing copies of this Final EIS to Federal, state, and local elected and appointed officials and agencies of government; Native American groups; national, state, and local environmental and public interest groups; and other organizations and individuals listed below. In addition, DOE is sending copies of the Final EIS to all persons who commented on the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* and the Supplement to the Draft EIS; these individuals are listed in Table CR-2 in the Comment-Response Document (Volume III of this Final EIS). DOE will provide copies to other interested organizations or individuals on request.

D.1 United States Congress

D.1.1 UNITED STATES SENATORS FROM NEVADA

The Honorable Harry Reid
United States Senate

The Honorable John Ensign
United States Senate

D.1.2 UNITED STATES SENATE COMMITTEES

The Honorable Harry Reid
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations

The Honorable Pete V. Domenici
Chairman
Subcommittee on Energy and Water Development
Committee on Appropriations

The Honorable Carl Levin
Ranking Member
Committee on Armed Services

The Honorable John Warner
Chairman
Committee on Armed Services

The Honorable Jeff Bingaman
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Committee on Energy and Natural Resources

The Honorable Frank H. Murkowski
Chairman
Committee on Energy and Natural Resources

The Honorable Robert Byrd
Ranking Member
Committee on Appropriations

The Honorable Ted Stevens
Chairman
Committee on Appropriations

The Honorable James Jeffords
Chairman
Committee on Environment and Public Works

The Honorable Robert Smith
Ranking Member
Committee on Environment and Public Works

D.1.3 UNITED STATES REPRESENTATIVES FROM NEVADA

The Honorable Jim Gibbons
United States House of Representatives

The Honorable Shelley Berkley
United States House of Representatives

D.1.4 UNITED STATES HOUSE OF REPRESENTATIVES COMMITTEES

The Honorable Sonny Callahan
Chairman
Subcommittee on Energy and Water Development
Committee on Appropriations

The Honorable Bob Stump
Chairman
Committee on Armed Services

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Chairman
Committee on Energy and Commerce

The Honorable Joe Barton
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Subcommittee on Energy and Air Quality
Committee on Energy and Commerce

The Honorable James V. Hansen
Chairman
Committee on Resources

The Honorable Don Young
Chairman
Committee on Transportation and Infrastructure

The Honorable Peter J. Visclosky
Ranking Minority Member
Subcommittee on Energy and Water Development
Committee on Appropriations

The Honorable Ike Skelton
Ranking Minority Member
Committee on Armed Services

The Honorable John D. Dingell
Ranking Minority Member
Committee on Energy and Commerce

The Honorable Rick Boucher
Ranking Minority Member
Subcommittee on Energy and Air Quality
Committee on Energy and Commerce

The Honorable Nick J. Rahall II
Ranking Minority Member
Committee on Resources

The Honorable James L. Oberstar
Ranking Minority Member
Committee on Transportation and Infrastructure

D.2 Federal Agencies

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Director, Division of Information Technology and Security
Defense Nuclear Facilities Safety Board

Ms. Andree DuVarney
National Environmental Coordinator
Ecological Sciences Division
Natural Resources Conservation Service
U.S. Department of Agriculture

Dr. Frank Monteferrante
Director, Compliance Review Division
Economic Development Administration
U.S. Department of Commerce

Mr. Rick Lemaire
Deputy for Environmental Planning, Education, and Training
Office of Environment, Safety and Occupational Health
Department of the Air Force
U.S. Department of Defense

Mr. Timothy P. Julius
Office of the Director of Environmental Programs
Office of the Assistant Chief of Staff for Installation Management
Department of the Army
U.S. Department of Defense

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Environmental Management Advisory Board
U.S. Department of Energy

Mr. Willie R. Taylor
Director
Office of Environmental Policy and Compliance
U.S. Department of the Interior

Mr. Michael Soukup/his replacement
Associate Director
Natural Resource Stewardship and Science
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U.S. Environmental Protection Agency

Ms. Cindy Cody
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Mr. David Tomsovic
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Federal Energy Regulatory Commission

Mr. Jim Wells
Director, Resources and Environment Issues
U.S. General Accounting Office

Mr. Lawrence Rudolph
General Counsel
National Science Foundation

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Chairman
U.S. Nuclear Regulatory Commission

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U.S. Nuclear Regulatory Commission

The Honorable Greta Joy Dicus
Commissioner
U.S. Nuclear Regulatory Commission

The Honorable Edward McGaffigan, Jr.
Commissioner
U.S. Nuclear Regulatory Commission

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U.S. Nuclear Regulatory Commission

Mr. E. Neil Jensen
U.S. Nuclear Regulatory Commission

Ms. Charlotte Abrams
U.S. Nuclear Regulatory Commission

Mr. James R. Firth
U.S. Nuclear Regulatory Commission

Mr. Martin J. Virgilio
U.S. Nuclear Regulatory Commission

Mr. King Stablein/gone
U.S. Nuclear Regulatory Commission

Mr. David B. Matthews
U.S. Nuclear Regulatory Commission

Mr. Donald P. Cleary/gone
U.S. Nuclear Regulatory Commission

Ms. Susan F. Shankman/gone
U.S. Nuclear Regulatory Commission

Mr. William Brach
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Appendix E

Environmental Considerations for Alternative Design Concepts and Design Features for the Proposed Monitored Geologic Repository at Yucca Mountain, Nevada

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E.1 Introduction

E.1.1 PURPOSE

The purpose of this appendix is to give the reader a perspective on the development of the conceptual design used for environmental impact analysis of the proposed Yucca Mountain Repository in this Final Environmental Impact Statement (EIS). The basic design concept of packaging spent nuclear fuel and high-level radioactive waste in corrosion-resistant, long-life containers for emplacement in drifts drilled into the unsaturated rock structure of Yucca Mountain has not changed from the design evaluated in the Draft EIS. The flexible design evaluated in this Final EIS does, however, include a number of features and alternatives that were not part of the Draft EIS design. The U.S. Department of Energy, (DOE or the Department) added these features and alternatives to the design primarily to increase operational flexibility, enhance long-term performance, and reduce long-term uncertainty. DOE presented the flexible design and evaluated its environmental impacts in the Supplement to the Draft EIS.

E.1.2 BACKGROUND

E.1.2.1 General Background

The preliminary conceptual design used for environmental analysis in the Draft EIS was described in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998, all), and was referred to as the Viability Assessment reference design. The Viability Assessment concluded that "uncertainties remain about key natural processes, the preliminary conceptual design and how the site and the design would interact" (DIRS 101779-DOE 1998, Overview, p. 2). Recognizing that the design would continue to develop, the Viability Assessment noted that "DOE is evaluating several design options and alternatives that could reduce existing uncertainty and improve the performance of the repository system" (DIRS 101779-DOE 1998, Overview, p. 30). DOE evaluated the design options in the License Application Design Selection project.

E.1.2.2 Background on the License Application Design Selection Project

Phase I of the License Application Design Selection project involved identifying and analyzing a set of design features and design alternatives that had potential value as elements in the repository design. Phase I was underway as the Draft EIS was being prepared. Accordingly, Appendix E of the Draft EIS contained a list of the design features and alternatives that had been developed to that point in time along with some very preliminary discussion of potential benefits and potential environmental impacts. Phase II of the License Application Design Selection project involved developing a set of enhanced design alternatives from combinations of the design alternatives and features prepared in Phase I. The following definitions of design features, design alternatives, and enhanced design alternatives, provide insight into how the process worked.

- Design alternative—Each design alternative represents a fundamentally different conceptual design for the repository and could stand alone as the License Application repository design concept. Design alternatives are distinguished from design features by their complexity and the number of attributes involved. Design alternatives, while not mutually exclusive, represent diverse and independent methods of accomplishing the repository mission—safe disposal of spent nuclear fuel and high-level radioactive waste. One example of a design alternative is a repository designed to use continuous natural ventilation to remove heat and moisture from the area of the waste packages after the repository has been closed.

- Design feature—A design feature is a particular element or attribute of the repository that could be added to a design alternative to enhance its performance. An individual design feature can represent a discrete concept, such as use of shielded waste packages, or a continuous range of values of some aspect of repository design, such as spacing of the waste emplacement drifts. Design features can be added to any design alternative singly or in combination, although the compatibility of different design alternatives and design features varies.

- Enhanced design alternative—Enhanced design alternatives are combinations of one or more design alternatives and design features that fit logical principles derived from the objectives for repository design. Enhanced design alternatives selected for evaluation are those combinations that include mutually compatible attributes and expected postclosure performance characteristics that exceed those of the basic design alternatives. Other characteristics considered in developing enhanced design alternatives include the compatibility of the design alternatives and design features; the developmental, operational, and maintenance simplicity of the resulting combination; and the ability of the set of enhanced design alternatives to address the entire set of design alternatives and design features.

The final *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all) recommended, and DOE subsequently chose, a particular combination of design alternatives and features called Enhanced Design Alternative II to carry forward in the design evolution. However, DOE did specify that backfill should be only a possible option in Enhanced Design Alternative II. Accordingly, DOE adopted Enhanced Design Alternative II without backfill as the design for continued development.

E.1.2.3 Background on the Science and Engineering Report

The current repository conceptual design, which is based on Enhanced Design Alternative II without backfill, is discussed in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (DIRS 153849-DOE 2001). This report was the basis for the Supplement to the Draft EIS and remains the basis for this Final EIS.

The flexible design described in the Science and Engineering Report and in the Supplement to the Draft EIS uses more extensive thermal management techniques to limit the heat released by the waste than the design evaluated in the Draft EIS. In addition to the design enhancements that would result directly from the proposed features and design alternatives discussed below, this design would be the most flexible in terms of accommodating other higher- or lower-temperature operating conditions.

The following sections identify and describe the design features and alternatives that DOE has considered in the design evolution of the repository. Some of the features and alternatives discussed in the following paragraphs have been incorporated in the current design. Most, while no longer being actively considered, have not been eliminated entirely. DOE expects the design to continue to evolve through the licensing process, so additional limited development and enhancement could occur as the design matures. The features and alternatives described below provide a framework for the design evolution that has occurred to date, and any future design evolution, along with a qualitative evaluation of environmental impacts.

E.1.3 SUMMARY OF DESIGN ALTERNATIVES AND FEATURES

The design alternatives and features considered in the development of the flexible design analyzed in the Final EIS are listed in Tables E-1 and E-2. The design alternatives and design features listed in Tables E-1 and E-2, respectively, are listed in the same order and with the same title as in the *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all). Design features 21 and 22, Dry Handling and Site Access Road, respectively, were not included in the License Application Design Selection study and neither was included in Appendix E of the Draft EIS, but they are currently being considered for future potential repository evolution. The titles include parenthetical comments in italics that are intended to help the reader identify the specific attributes of the alternatives and features.

Table E-1. Design alternatives.

Alternative	Title	Text	Purpose	Status
1	Tailored Waste Package Spatial Distribution *(to improve heat distribution in the drifts)*	E.2.1.1	HM	CI
2	Low Thermal Load *(about 25 MTHM/acre)*	E.2.1.2	HM	PA
3	Continuous Postclosure Ventilation *(natural ventilation)*	E.2.1.3	HM	CI
4	Enhanced Access *(shielding to permit personnel access to the emplacement drifts)*	E.2.1.4	CO	CI
5	Modified Waste Emplacement Mode *(use natural shielding such as vertical emplacement of waste packages to permit personnel access)*	E.2.1.5	CO	CI
6	Viability Assessment Design *(85 MTHM/acre)*	E.2.1.6	HM	CI
7	Viability Assessment Design with Options *(ceramic coating, backfill and drip shield[a])*	E.2.1.7	HM	CI
8	Modular Design (Phased Construction) *(phased construction of facilities to provide funding flexibility)*	E.2.1.8	CO	AE

a. Drip shields are listed as a design feature in Table E-2.

The tables include a column titled text, which lists the section of this appendix that contains additional description of the alternative or feature.

The column titled Purpose indicates the purpose or nature of the alternative or feature with respect to repository performance. The codes for the entries are:

Purpose of design alternative or feature:

RT— Enhance the barrier to prevent release and transport of fission products

HM— Control heat and moisture in the repository to reduce the potential for corrosion of the waste packages

CO— Support cost and operation considerations

The column titled Status indicates the current disposition of each alternative or feature as follows:

Status:

PA— Included in the impact analysis of the flexible design for the Proposed Action

AE— Additional evaluation to be conducted

CI— Currently inactive *(but not eliminated from further consideration)*

NF— Not considered feasible in conjunction with the flexible design

Table E-2. Design features.

Feature	Title	Text	Purpose	Status
1	Ceramic Coatings *(on the waste package)*	E.2.2.1	RT	CI
2	Backfill *(in the emplacement drifts)*	E.2.2.2	RT	CI
3	Drip Shield *(over the waste package)*	E.2.2.3	RT	PA
4	Preemplacement Aging and Blending of Waste *(commercial spent nuclear fuel only)*	E.2.2.4	HM	PA
5	Continuous Preclosure Ventilation *(both forced ventilation and natural ventilation of emplacement drifts)*	E.2.2.5	HM	PA/AE[a]
6	Rod Consolidation *(commercial spent nuclear fuel only)*	E.2.2.6	HM	CI
7	Timing of Repository Closure and Maintenance of Underground Facilities and Ground Support *(consideration of the repository being open for 300 years or more)*	E.2.2.7	HM	PA
8	Drift Diameter *(of the emplacement drifts)*	E.2.2.8	HM	CI
9	Waste Package Spacing and Drift Spacing	E.2.2.9	HM	PA
10	Waste Package Self Shielding	E.2.2.10	CO	CI/NF
11	Waste Package Corrosion Resistant Materials	E.2.2.11	RT	PA
12	Richards Barrier *(to divert moisture away from the waste package by capillary action)*	E.2.2.12	HM	CI
13	Diffusive Barrier/Getter Under the Waste Package	E.2.2.13	RT	CI
14	Canistered Assemblies *(for commercial spent nuclear fuel only)*	E.2.2.14	RT	CI
15	Additives and Fillers *(inside the waste package)*	E.2.2.15	RT	CI
16	Ground Support Options *(to prevent rockfall in the emplacement drifts*	E.2.2.16	RT	PA
17	Near-Field Rock Treatment during Construction *(to limit seepage of water into the drifts)*	E.2.2.17	HM	CI
18	Surface Modifications *(to limit infiltration of water into the mountain)*	E.2.2.18	HM	CI
19	Repository Horizon Elevation	E.2.2.19	CO	CI
20	Higher Thermal Loading	E.2.2.20	HM	CI
21	Dry Handling *(of commercial spent nuclear fuel in the Waste Handling Building)*	E.2.2.21	CO	AE
22	Site Access Road *(from U.S. 95 to the North Portal on the west side of Fortymile Wash)*	E.2.2.22	CO	AE

a. Natural ventilation for the preclosure period is undergoing additional evaluation.

The tables indicate that eight alternatives and 22 features have been identified for consideration in finalizing the repository design. One alternative and seven features have been integrated into the flexible design analyzed for the Proposed Action in the Supplement to the Draft EIS and in the Final EIS. One additional alternative and three additional features will be evaluated further as the design matures. The six alternatives and 13 features that are listed as currently inactive (CI) have not been eliminated from consideration, but they were not considered in the environmental impact analysis for the Final EIS. Self shielding of waste packages, feature 10, is not considered feasible in conjunction with the waste package design used for the Final EIS.

The following sections provide brief descriptions of each of the alternatives and features. For the alternatives and features that are subject to additional evaluation (status AE), preliminary information on potential benefits and environmental impacts is provided. The benefits and impacts for the alternatives and features included in the flexible design (status PA) are discussed in the body of the Final EIS; for those with an inactive status (CI), the potential benefits and impacts have not been discussed.

E.2 Design Alternatives and Features

The summary descriptions of the design alternatives and features provided in the following sections are composite descriptions using data and text from both Appendix E of the Draft EIS and from the *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all). The *License Application Design Selection Report* provides references for additional data and information on many of the design alternatives and features.

E.2.1 DESIGN ALTERNATIVES

As mentioned above, the *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all) and this Appendix discusses eight design alternatives. Six of these alternatives are currently inactive and DOE did not consider them in the impact analysis for this EIS. One of the draft alternatives, low thermal load, has been incorporated in the flexible design evaluated in the Proposed Action. The remaining alternative, Modular Design, would be evaluated further as the final repository design matures. The following sections provide a brief description of the design alternative from the *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all). For the modular design, DOE has also provided a qualitative assessment of the potential benefits and environmental considerations should DOE adopt this alternative at a later time.

E.2.1.1 Design Alternative 1, Tailored Waste Package Spatial Distribution

This design alternative addresses the position and placement of specific types of waste in the repository block emplacement drifts to determine if the postclosure isolation performance of the repository could be improved. The Draft EIS design emplaced the waste packages in the order received, with the only restrictions being the total amount of heat per acre and adjacent package heat considerations. This design alternative evaluation identifies combinations of site characteristics and waste forms and packages that would provide improved waste isolation performance and that practicable engineering could support. An example application would be grouping waste package types into categories of hot, medium, and cold to even the temperature differences across the repository or in a drift.

E.2.1.2 Design Alternative 2, Low Thermal Load

The low thermal load design alternative formed the basis for the flexible design evaluated in the Supplement to the Draft EIS and the Final EIS. The basic premise of this alternative is that a lower thermal load would limit the temperature of the drift wall and host rock and, thereby, would reduce uncertainties in predicting thermal, chemical, mechanical, and hydrological effects. As demonstrated in the Supplement to the Draft EIS and this Final EIS, the lower-temperature repository operating mode could be achieved by varying certain operational parameters such as waste package spacing, ventilation rate and duration, and waste package loading.

E.2.1.3 Design Alternative 3, Continuous Postclosure Ventilation

The postclosure ventilation design alternative identifies a series of conceptual designs aimed at utilizing ventilation in the emplacement drifts during the postclosure period. The expected benefit provided by postclosure ventilation would be improved waste package performance. Improved performance could be achieved by limiting the amount of water or humidity contacting the waste packages, which would reduce corrosion. A ventilated repository could reduce the emplacement drift air temperature, as well as the relative humidity, rock saturation, and rock temperature.

E.2.1.4 Design Alternative 4, Enhanced Access

This design alternative considers the approach of providing sufficient radiation shielding for the waste packages to allow personnel access during handling and inspection operations. This, in turn, would simplify component design and operations. Access to the emplacement drifts would be provided so personnel could execute performance confirmation activities and maintenance.

E.2.1.5 Design Alternative 5, Modified Waste Emplacement Mode

In this design alternative, unshielded waste packages would be placed in a configuration where the repository's natural or engineered barriers would provide the personnel shielding. This alternative is similar to the enhanced access design in that personnel could access areas near the waste packages, but in this design alternative the waste packages would not have to be shielded. Various configurations for accomplishing the shielding using the natural and engineered barriers would be considered. Examples include placing waste packages in boreholes drilled into the floor or wall of emplacement drifts, in alcoves off the emplacement drifts, in trenches at the bottom of the emplacement drifts, or in short cross-drifts excavated between pairs of excavated drifts. In each case, some type of cover plug would be used to shield radiation in the emplacement drifts.

E.2.1.6 Design Alternative 6, Viability Assessment Reference Design

The Viability Assessment reference design is equivalent to the high thermal load alternative (85 MTHM per acre) evaluated in the Draft EIS. The complete description of this design is presented in Chapter 2 of the Draft EIS.

E.2.1.7 Design Alternative 7, Viability Assessment Reference Design with Options

The Viability Assessment reference design with options was considered as a design alternative in the License Application Design Selection process. Options considered include ceramic coatings, backfill, and drip shields (see Sections E.2.2.1, E.2.2.2, and E.2.2.3, respectively).

E.2.1.8 Design Alternative 8, Modular Design (Phased Construction)

This design alternative considers the effects of separating the Waste Handling Building, the Carrier Preparation Building, and the subsurface repository into multiple modules, structures, or phases to be constructed over time. Direct support facilities such as the Waste Treatment Building, the balance of the plant support facilities, and any additional facilities required for the support of early receipt or storage could also be phased.

Six alternative design concepts were considered to determine the impact on waste throughput quantities. These concepts were reviewed to determine how they would perform in relation to funding constraints, waste receipt and storage, and emplacement rates. Subsurface construction and phasing to meet estimated emplacement rates were reviewed to determine the most effective method.

DOE would evaluate this design alternative further as the repository design matures, and as funding forecasts were identified.

E.2.1.8.1 *Potential Benefits*

Modular design is an alternative that could reduce annual expenditures during construction if annual funding is constrained below that required for the Proposed Action.

E.2.1.8.2 *Potential Environmental Considerations*

Modular design is an alternative that would probably increase the total facility cost and the environmental impacts by about 20 to 30 percent. Constructing multiple facilities to handle the same capacity would increase nearly all impacts because many systems (for example, ventilation systems) would need to be partially duplicated and total building floor space would increase. In addition, construction of the later

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facilities would be carried out in parallel with nuclear operations on the site, which would result in the need for careful control and monitoring of construction activities. All of the impacts would likely be extended over a longer period. Annual impacts could remain nearly the same but total impacts would be likely to increase.

E.2.2 DESIGN FEATURES

This section describes the 22 design features, 20 of which DOE evaluated as part of the *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all). Seven of these features have been incorporated (some only partially) in the flexible design evaluated in the Proposed Action. Based on the current design, 13 of the features are either inactive or not feasible. For the features that are being evaluated for incorporation as the design matures, DOE has provided a qualitative assessment of their potential benefits and potential environmental considerations.

E.2.2.1 Ceramic Coatings

A thin coating [1.5 millimeters (0.06 inch) or more] of a ceramic oxide on the outer surface of the waste package could increase the life of the waste package by slowing the rate at which the waste package corroded. Several thermal processes produce high-density coatings on metals, and the range of materials that can be applied is extensive. The coating materials that could be considered include magnesium aluminate spinel, aluminum oxide, titanium oxide, and zirconia-yttria. This design feature is no longer under active consideration, but it remains as a potential additional design feature if needed to broaden the scope of defense-in-depth (DIRS 107292-CRWMS M&O 1999, Section 5.1.5.1).

E.2.2.2 Backfill

At repository closure, loose, dry, granular material such as sand or gravel would be placed over the waste packages in a continuous, heaped pile. Other materials for backfill, such as crushed rock and depleted uranium, could be considered. The waste packages would generate heat after emplacement, and this heat would tend to drive water away from the emplacement location. Backfill would act as insulation for the waste packages, keeping them hotter. The emplacement areas would stay hotter longer, which could retard the onset of waste package corrosion by delaying the onset of water contacting the packages. The waste packages would gradually cool off and become potentially vulnerable to corrosion caused by water and corrosive minerals dissolved in the water. In addition to providing thermal insulation, the backfill (without proposed drip shields) would provide some protection to the waste package from rockfall. This design feature is no longer under active consideration.

As discussed in Chapter 2, Section 2.1.2.4, backfill would be used for the Proposed Action for main drifts, access ramps, and ventilation shafts. The backfill for these drifts and shafts would be installed during closure. Backfill is not currently planned for use in the emplacement drifts.

E.2.2.3 Drip Shields

Drip shields over the waste packages would provide a partial barrier by diverting falling rocks and infiltrating water away from waste packages in an emplacement drift. Corrosion-resistant metals (titanium or Alloy-22), metals with ceramic coatings, and monolithic ceramics have been considered as drip shield materials. One option would be to place drip shields under backfill; another would be to place the drip shields over the backfill. Drip shields could be implemented with or without backfill.

The drip shield, if used over the backfill, would be formed to the approximate backfill surface profile and placed atop the backfill (or Richards Barrier). With this option, the drip shield would be placed in conjunction with the placement of backfill at repository closure.

For the Final EIS, DOE has incorporated the use of drip shields without backfill as part of the Proposed Action.

E.2.2.4 Aging and Blending of Waste

Pre-emplacement aging and blending of commercial spent nuclear fuel would provide mechanisms for managing the thermal output of a waste package and the total thermal energy that the repository would have to accommodate.

Aging the waste before emplacement would result in less variable (over time) thermal output of the waste packages and lower waste package temperatures.

Blending would allow a more uniform heat output from the waste packages. Blending would be accomplished by selecting waste forms for insertion in waste packages based on their heat output to minimize the variability in the thermal energy of each waste package and to lower peak waste package heat output.

Aging and blending would not be necessary for DOE spent nuclear fuel and high-level radioactive waste.

Both aging and blending would require additional facilities at the repository. A 5,000-MTHM-equivalent storage pool would be required to support blending and a large surface storage pad along with large storage casks would be required to support aging. The capability to age and blend commercial spent nuclear fuel has been incorporated as part of the Proposed Action in this Final EIS.

E.2.2.5 Continuous Preclosure Ventilation

During preclosure, a ventilation system would deliver a specified volume of air to the emplacements drifts containing waste packages. This continuous ventilation would reduce air and drift temperatures, and would carry away heat and moisture that could otherwise increase corrosion. The host rock would remain drier and cooler during preclosure compared to a repository (such as the Draft EIS design) where there was little ventilation.

The ventilation could be provided using forced flow driven by electric-motor-powered fans or by natural ventilation. Forced-flow ventilation is included in the Proposed Action and is discussed in Volume I of this Final EIS. The heat generated by the spent nuclear fuel and high-level radioactive waste could develop and maintain a temperature difference to drive passive ventilation of the emplacement drifts throughout the maximum time the repository would remain open. This is called *natural ventilation*. The heat from the waste could be used to draw cooler, drier external air through the intake shafts, across the emplacement drifts, and out the exhaust shafts (located at an elevation above the intakes), much the way heat from a fireplace draws air from a room and exhausts it through a chimney. Passive ventilation is used to regulate air temperature in buildings and has similar uses in large subsurface structures such as mines. Findings in numerous caves that are analogous to a deep geologic repository (DIRS 153849-DOE 2001, Section 2.1.5.4) support the idea that the environment of a naturally ventilated underground system could, under certain conditions, preserve materials for several thousand years and could greatly reduce waste package degradation.

Natural ventilation during preclosure is the subject of additional evaluation for potential future repository evolution. The environmental impacts of natural ventilation were evaluated in one of the lower-temperature operating modes for this Final EIS. Methods for implementing this feature would require further evaluation, as discussed below.

E.2.2.5.1 *Potential Benefits*

The primary benefit of natural ventilation for the removal of heat and moisture would be the reduction in energy use and reduction in maintenance compared to systems using forced-flow ventilation driven by electric fans, potentially required to operate for hundreds of years. Benefits of forced-flow ventilation are addressed in Chapter 2 as part of the Proposed Action.

E.2.2.5.2 *Potential Environmental Considerations*

Additional excavation could be required to optimize the repository configuration for natural ventilation. The actual number of emplacement drifts might not change, but the layout of drifts could vary slightly to accommodate additional or reoriented ventilation shafts. The sizes of the shafts might have to be increased. A backup forced ventilation system could be needed to provide “blast cooling” to support maintenance. Environmental impacts of forced-flow ventilation are addressed in Chapter 4 as part of the Proposed Action.

E.2.2.6 Rod Consolidation

Both pressurized-water reactor and boiling-water reactor fuel assemblies have fuel rods arranged in regular square arrays with rod-to-rod separations maintained by fuel assembly hardware. Rod consolidation would involve taking the fuel rods out of the arrays and bringing them into direct contact with one another. This would reduce the volume required by fuel assemblies and would allow increases in the capacity of waste packages or reduction in waste package size. The fuel assemblies would be consolidated by removing the fuel rods from the assembly and placing them in a canister. Each canister could contain fuel rods from one or more fuel assemblies. The canisters would then be loaded into the waste package. Nonfuel components (control rods, channels, etc.) would be separated from the fuel assemblies for disposal by other methods. The remainder of the assembly hardware would be disposed of separately. The consolidation process could occur in a pool or shielded dry environment. This design feature is no longer under active consideration because the concentration of thermal energy inherent in rod consolidation is not consistent with the flexible design operating modes.

E.2.2.7 Timing of Repository Closure and Maintenance of Underground Facilities and Ground Support

The timing of the repository closure design feature addresses the changes in performance criteria that result from consideration of a monitoring phase as long as 300 years, rather than the 100-year period from initiation of waste emplacement used in the Draft EIS design. Included in the design feature were requirements to facilitate keeping the repository open for an additional 200 years, the related cost implications, and a risk assessment. The maintenance of underground facilities and ground support design features was included in this design feature because the two features would be interrelated. Underground facilities and ground support would affect the level of maintenance in the emplacement drifts needed to accommodate an extended long-term repository service life. One benefit of a maintenance program would be that it could reduce the risk of rockfall in the emplacement drifts. This feature is included as part of the Proposed Action lower-temperature operating mode.

E.2.2.8 Drift Diameter

The diameter of the emplacement drift is influenced by a number of primary design features. Heat management strategies, emplacement mode, and emplacement equipment are major influencing factors. The size of the emplacement drift could directly affect design considerations such as opening stability (rockfall potential), the extent of the mechanically induced disturbed zone, and the amount and location of moisture seepage into the drifts. These design considerations could affect repository performance. The drift diameter for the Draft EIS design was 5.5 meters (18 feet). The 5.5-meter drift diameter was maintained in the Supplement to the Draft EIS and in this Final EIS. DOE is not actively considering a change in drift diameter because other drift diameters do not enhance the performance or operation of the flexible design operating modes. The drift diameter for the flexible design was standardized at 5.5 meters (DIRS 107292-CRWMS M&O 1999, Section 5.1.5.4).

E.2.2.9 Drift Spacing and Waste Package Spacing

Drift spacing is the distance between two consecutive drifts. Waste package spacing is the distance between the ends of two consecutive waste packages. For a given drift spacing, emplacement of waste packages can be arranged by using point load (waste package spacing based on individual package characteristics, such as mass content or equivalent heat output), or line load [waste packages emplaced nearly end to end with a 0.1-meter (0.3-foot) gap and with no consideration of individual waste package characteristics].

The point load approach to thermal analysis was used for the scenarios evaluated in the impact analysis for the Draft EIS design. Waste package spacing was based on the mass content of waste packages, to achieve an overall area mass loading from 25 MTHM per acre to 85 MTHM per acre for commercial spent nuclear fuel. The higher-temperature repository operating mode evaluated in the Final EIS is a line load configuration with 0.1-meter (0.3-foot) waste package spacing and 81-meter (270-foot) drift spacing. The lower-temperature repository operating mode evaluated in the Final EIS uses the 81-meter drift spacing but considers spacing ranging from about 2.1 to 6.4 meters (6.9 to 21 feet).

E.2.2.10 Waste Package Self-Shielding

In the repository designs evaluated to date, handling of waste packages in the emplacement drifts would be performed remotely, and human access to the emplacement drifts would be precluded if waste packages were present. Waste package self-shielding would reduce the radiation in the drifts to levels such that personnel access would be possible. This would allow direct access to the performance confirmation instrumentation, and for maintenance and repair in the drifts.

Self-shielding would be accomplished by adding a shielding material around the waste packages. Candidate materials include A516 carbon steel, concrete with depleted uranium (Ducrete®), magnetite concrete, and a composite material of boron-polyethylene and carbon steel.

The amount of shielding would depend on the target radiation dose level in the drift environment. Because the amount of shielding would substantially increase the weight and size of the loaded waste packages, it is not considered feasible with the current waste package design. This design feature is no longer under active consideration.

E.2.2.11 Waste Package Corrosion-Resistant Materials

The Draft EIS design for the waste package used two concentric barrier layers: an outer A516 carbon steel corrosion-allowance material that would provide structural strength during handling, and an inner nickel-based Alloy-22 corrosion-resistant material. These two barriers would be expected to provide substantially complete containment of the waste for the lifetime goals established in the Viability Assessment; however, a waste package with the capability to provide substantially complete containment for a significantly extended lifetime would improve long-term performance.

An upgrade of the waste package design replaced the corrosion-allowance barrier with a corrosion-resistant barrier and was evaluated in the Supplement to the Draft EIS and this Final EIS. Several combinations of materials were considered for the inner and outer layers. The combination selected was an outer shell of nickel-based Alloy-22 corrosion-resistant material and a stainless-steel (Type 316NG) inner shell, which would provide structural strength and corrosion resistance.

E.2.2.12 Richards Barrier

A Richards Barrier would be a special type of backfill consisting of a fine-grained material, such as sand, covering a coarse-grained material, such as gravel. The coarse-grained material, in turn, would cover the waste package, with the fine-grained material acting as a cap or cover for the coarse-grained material. The Richards Barrier would use the difference in permeability between the two backfill materials to divert water. Water entering the emplacement drift would flow in the fine-grained material and not enter the coarse-grained material. The water would travel to the edge of the fine-grained material and reenter the surrounding rock mass through cracks. This design feature is not considered necessary to meet the design and performance criteria for the flexible design, but it remains as a potential additional design feature if needed to broaden the scope of defense-in-depth (DIRS 107292-CRWMS M&O 1999, Section 5.1.5.1).

E.2.2.13 Diffusive Barrier/Getter Under the Waste Package

The diffusive barrier component would be a loose, dry, granular material placed in the intervening space beneath each waste package and above the bottom of the emplacement drift to a sufficient depth and degree of compaction that would form a restrictive barrier to seepage. The getter component, a fine-grained material with an affinity for radionuclides, would be mixed with a matrix material and dumped into the invert recess. The combined material would be placed around the structural supports of the waste package to eliminate voids when the waste package was emplaced. This design feature is no longer under active consideration because of uncertainties in the long-term performance improvement of the repository and uncertainties in the long-term effectiveness of the material (DIRS 107292-CRWMS M&O 1999, Section 5.1.7.1).

E.2.2.14 Canistered Assemblies

Placing commercial spent nuclear fuel assemblies in canisters at the Waste Handling Building before inserting them into disposal containers would provide an additional barrier and further limit mobilization of radionuclides if the waste package was breached. The canisters would be fabricated from a corrosion-resistant material (for example, Alloy-22 or a zirconium alloy). There would be three general concepts for the placement of fuel assemblies in canisters: (1) Canisters could be designed to hold individual fuel assemblies; (2) Canisters could be designed to hold a few assemblies, and (3) A large canister could be designed to hold multiple fuel assemblies and fit one canister per waste package. This design feature is not considered necessary to meet the design and performance criteria for the flexible design, but it remains as a potential additional design feature if needed to broaden the scope of defense-in-depth (DIRS 107292-CRWMS M&O 1999, Section 5.1.5.1).

E.2.2.15 Additives and Fillers

Waste package additives and fillers (henceforth referred to simply as fillers) are materials that could be placed in a loaded waste package to fill the void spaces. These materials could have the following benefits for performance of the engineered barrier system: (1) retardation of radionuclide release from a breached waste package by absorbing radionuclides and providing resistance to advective transport; (2) displacement of the moderator from the interior of the waste package to provide additional defense-in-depth for criticality control; and (3) limitation on the amount of oxygen available for waste form alternation. In addition, various waste package filler options could provide such benefits as serving as a mechanical packing to inhibit movement of the waste form in the package, creating a barrier to the release of particulate radionuclides during a design-basis event, or providing cathodic protection of fuel and basket material. The disadvantages of additives and fillers include adding weight to the waste package, introducing the potential for additional corrosion or chemical reaction, and complicating the removal of material from the waste package if necessary following retrieval. This design feature is not considered necessary to meet the design and performance criteria for the flexible design, but it remains as a potential additional design feature if needed to broaden the scope of defense-in-depth (DIRS 107292-CRWMS M&O 1999, Section 5.1.5.1).

E.2.2.16 Ground Support Options

Ground support in the repository is intended to ensure drift stability before closure. The selection of ground support options could affect repository waste isolation performance. Consideration of ground support options included functional requirements for ground support, the use of either concrete or steel-lined systems, and the feasibility of using an unlined drift ground support system with grouted rock bolts.

A concrete lining has been studied for its structural/mechanical behavior and subjected to the load conditions expected of emplacement drifts. A concrete lining in the emplacement drifts was evaluated in the impact analysis for the Draft EIS. However, a number of postclosure performance assessment issues related to the presence of concrete in the emplacement drift environment have been identified.

An all-steel ground support system (for example, steel sets with partial or full steel lagging) has been considered a viable ground support candidate for emplacement drifts. The use of an all-steel lining system would provide a way to limit or eliminate the introduction of cementitious materials (that is, concrete, shotcrete, or grout), including organic compounds, into the emplacement drift environment. The potential for corrosion of steel subjected to the emplacement drift environment is a concern with this system. For the Supplement to the Draft EIS and this Final EIS, the all-steel ground support system for the emplacement drifts and a concrete liner support system for the main drifts and ventilation shafts were included as part of the Proposed Action.

E.2.2.17 Near-Field Rock Treatment

The function of rock treatment would be to limit the amount of water than could seep into the drift. The treatment would consist of injecting low-permeability grout into the cracks in a portion of the rock overlying each drift to lower the hydraulic conductivity of the rock in the treated zone. This would decrease seepage into the drift and thus reduce the amount of water that could contact the waste packages during postclosure. To meet seepage criteria, the rock treatment would have to perform while seepage toward the emplacement drift occurred.

Injection would start at least 6 meters (20 feet) above the drift crown and would form a zone at least 4 meters (13 feet) thick, extending at least 6 meters on each side of the drift. Injection would be through holes 2.5 to 5 centimeters (1 to 2 inches) in diameter drilled from inside each drift prior to waste emplacement. Injection pressures would not exceed a certain minimum pressure, selected to limit rock fracturing or joint opening. The candidate materials include Portland cement grout, sodium silicate, bentonite (a clay), and calcite. This design feature is no longer under active consideration because it had limited potential to improve postclosure repository performance and its cost was high (DIRS 107292-CRWMS M&O 1999, Section 5.1.7.2).

E.2.2.18 Surface Modification

Surface modifications could be a way to significantly reduce or eliminate the amount of water that could seep into the mountain from the surface and reach the waste packages. Two modification options were considered. The first option (alluvium option) would be to alter the ground surface to encourage natural removal of water to the atmosphere by evaporation from the ground surface and deep water removal by transpiration from plants. To cover the mountain with alluvium, the surface of the mountain would be modified to prevent the alluvium from washing away. Ridge tops on the eastern flank of Yucca Mountain would be removed and the excavated rock placed in Solitario Canyon and Midway Valley or used to fill the alluvium borrow pit. The maximum slope of the ground surface remaining would be approximately 10 percent. Alluvium approximately 2 meters (7 feet) thick would be placed on the new surface and vegetation would be established.

The second option (drainage option) is to alter the surface drainage to promote the rapid runoff of surface water by removing the thin layer of alluvium on the hilltops and slopes to expose the bedrock. It has been shown that where the alluvium is thin, it retains the surface water and allows it to infiltrate the unsaturated zone. Where bedrock is exposed on slopes, water runs off rapidly and net infiltration is very small or reduced to zero. The thin alluvium layer would be stripped from the topographic surface above the repository footprint and a 300-meter (980-foot) buffer surrounding it. This design feature is no longer under active consideration since the lifetime of the alluvium layer was uncertain and the long-term effects of increased runoff could not be predicted. The feature also resulted in large short-term environmental impacts due to the extensive surface modification (DIRS 107292-CRWMS M&O 1999, Section 5.1.7.3).

E.2.2.19 Repository Horizon Elevation

Two basic design concepts were considered for the repository horizon elevation feature. The first concept would be to relocate the repository to a higher evaluation. The higher elevation would be excavated in a single lithophysal unit, specifically the upper lithophysal unit. The second concept would be of a two-tier repository. This concept could allow for repository expansion if a decision was made to increase the waste inventory, provide performance improvements through thermal hydraulic effects, and increase flexibility in waste package emplacement strategies. This design feature is no longer under active consideration because further evaluation indicated severe construction problems including very steep access drifts, and the two-tier concept could not be shown to offer long-term performance improvement (DIRS 107292-CRWMS M&O 1999, Section 5.1.7.4).

E.2.2.20 Higher Thermal Loading

This feature would increase the thermal loading of the repository by placing the waste packages close together, thereby increasing the density of heat sources in the repository. Although the total heat would not increase, it would be more concentrated because the repository would occupy a smaller area. This closer packing of waste packages could be done in one of three ways. The emplacement drifts could be excavated closer to one another. The waste packages would be placed closer together in each drift, with the emplacement drifts at their original reference spacing. The third possibility combines the first two options, resulting in closely spaced waste packages in closely spaced drifts. In all cases, the increased number of waste packages in a given area would create a higher concentration of heat, resulting in a higher thermal load to a given area of the repository. This design feature is no longer under active consideration.

E.2.2.21 Dry Handling of Spent Fuel in the Waste Handling Building

A dry handling capability in the Waste Handling Building would facilitate the handling of fuel assemblies, canisters, and waste packages in a dry environment. In addition, it would provide dry storage facilities for the temporary storage of fuel assemblies to support blending. The Waste Handling Building design would include hot cells, transfer facilities, and isolated maintenance cells to support receipt of truck and rail transportation casks, unloading of fuel assemblies and canisters from casks, opening of dual-purpose canisters, unloading of fuel assemblies from dual-purpose canisters, transfer of fuel assemblies to and from dry storage vaults, loading of fuel assemblies into disposal containers, transfer of filled disposal containers to the disposal container cell for emplacement preparation, and preparation of the empty transportation cask and dual-purpose canisters for offsite shipment. Two identical dry assembly transfer system lines and one dry canister transfer system would support the planned throughput rate. The estimated capacity of the dry fuel storage system would be 5,000 MTHM to support blending of the waste such that no waste package exceeded 11.8 kilowatts. This design feature might be considered and evaluated further in the future.

E.2.2.21.1 *Potential Benefits*

The dry handling approach potentially would have several operational advantages over the wet handling approach. A significant advantage is that the estimated throughput rate for the dry handling system would be about a third higher than that for an equivalent wet system, which would increase operational flexibility. Liquid wastes and worker doses during operation would be reduced substantially with respect to the corresponding values for a wet system. The dry handling approach would eliminate the need for assembly cooling in the cask preparation step and for drying the assemblies prior to disposal container loading. Dry handling would also eliminate the need to dewater shipping casks after unloading. In general, it would be an advantage to eliminate some of the challenges associated with water in pools and wet handling.

E.2.2.21.2 *Potential Environmental Considerations*

The space required for the dry handling facility would be about the same as the space required for equivalent wet handling if commercial spent nuclear fuel blending was not needed. If commercial spent nuclear fuel blending was required, the dry handling/storage facility would be larger than the wet facility because the spent nuclear fuel stored dry would have to be spaced farther apart than in wet storage. Accordingly, DOE could have to expand the overall Waste Handling Building site to accommodate dry handling. The use of construction materials such as concrete and steel would increase for the dry handling facility. As mentioned above, the dry handling approach would reduce worker doses and the generation of liquid waste. Conversely, the cost of building the dry handling facilities would be higher but the operation costs would be equal or less than those for wet handling.

E.2.2.22 Site Access Road

A new site access road would enable more direct, efficient, and safe travel for personnel and transportation of materials. A conceptual plan for the new access road involves the construction of an approximately 32-kilometer (20-mile) section of roadway from Amargosa Valley (formerly known as Lathrop Wells) at U.S. Highway 95 near the southwest corner of the Nevada Test Site to the Yucca Mountain site. The road would run in a predominantly northerly direction parallel to Fortymile Wash and would terminate at the Yucca Mountain site in the vicinity of the North Portal. Figure E-1 shows the route being considered. The road would have two 3.7-meter (12-foot)-wide travel lanes, and 2.4-meter (8-foot)-wide shoulders, and would consist of a 15-centimeter (6-inch)-asphaltic concrete pavement over a 30-centimeter (12-inch) aggregate base. This design feature might be considered and evaluated further in the future.

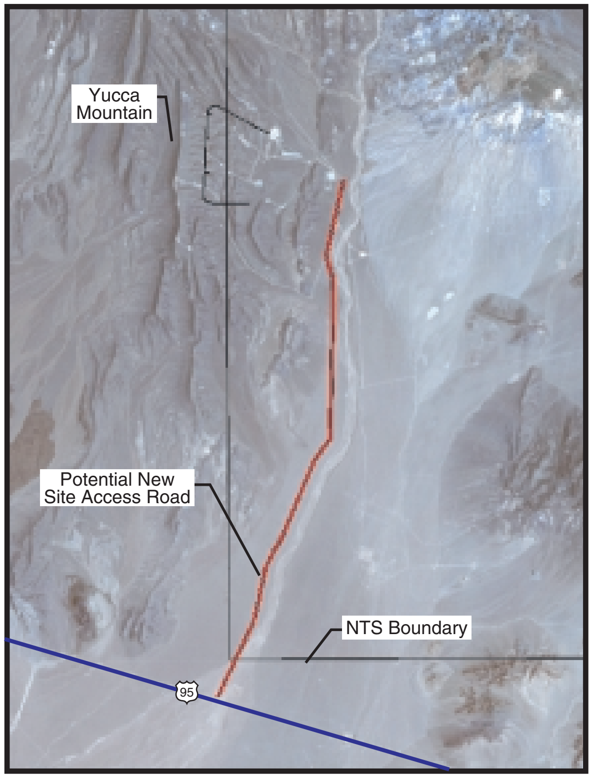

Figure E-1. Site access road.

E.2.2.22.1 *Potential Benefits*

The primary benefit from constructing a new site access road would be to facilitate more direct, efficient, and safe travel to the Yucca Mountain site. Current highway access to the Yucca Mountain site from the Las Vegas area to the east is by U.S. Highway 95 to the Mercury interchange near the southwest corner of the Nevada Test Site. From the Mercury interchange, the route travels about 110 kilometers (70 miles) to the Yucca Mountain site on existing roads that are old, narrow, and indirect, passing through about 10 intersections. Highway access from the west is by the existing Lathrop Wells Road for about 42 kilometers (26 miles) from U.S. 95 to the Yucca Mountain Site Central Support Site and then on to the site over about 27 kilometers (17 miles) of existing Nevada Test Site roads.

The new site access road would provide repository access from the Las Vegas area by travelling about 97 kilometers (60 miles) west past the Mercury interchange on U.S. 95 to the interchange at Amargosa Valley and then on the 32-kilometer (20-mile) section of newly constructed road to the repository site. Although this route would be about 16 kilometers (10 miles) longer than the existing route, it would be at least 10 to 20 percent faster and much safer, especially for transport vehicles carrying construction materials. Access to the repository site from the west would be directly from U.S. 95 on the 32-kilometer (20-mile)-long new access road and would be about half the distance of using the existing Nevada Test Site roads.

E.2.2.22.2 *Potential Environmental Considerations*

DOE would have to evaluate the environmental impacts of constructing the site access road. The 32-kilometer (20-mile)-long road would have about 12-meter (40-foot)-wide pavement and an assumed standard 3:1 slope and drainage beyond the paved shoulders, so the total road width would be about

24 meters (80 feet). The minimum total permanently disturbed area resulting from the construction of the road would be about 0.87 square kilometer (194 acres). Additional temporary disturbed area could occur from construction facilities, borrow pits, and laydown areas, which could total as much as 0.081 square kilometer (20 acres). These areas would be evaluated in an environmental survey to ensure that the impacts of constructing the access road were acceptable. The survey would focus on land use and ownership, cultural resources, hydrology, soils, and biological resources in and along the route. In addition, it would consider air quality, the safety of workers travelling the road, socioeconomic issues, and construction materials on a comparative basis with current routes.

E.3 Enhanced Design Alternatives

Enhanced Design Alternatives are combinations of the alternatives and design features described in the preceding sections. These concepts were developed to cover a range of potential repository designs as part of the License Application Design Selection Process described in Section E.1.2. Enhanced Design Alternatives are intended to be improvements to the basic design alternatives discussed in Section E.2. Five Enhanced Design Alternatives were developed in the License Application Design Selection project. As stated in Section E.1.2.2, DOE chose Enhanced Design Alternative II for continued development and as the basis for the Final EIS analysis. For a description of the other Enhanced Design Alternatives, the methods used to evaluate them, and the results of the evaluations see the final *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all).

REFERENCES

107292	CRWMS M&O 1999	CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) 1999. *License Application Design Selection Report.* B00000000-01717-4600-00123 REV 01 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990908.0319.
101779	DOE 1998	DOE (U.S. Department of Energy) 1998. *Viability Assessment of a Repository at Yucca Mountain.* DOE/RW-0508. Overview and five volumes. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19981007.0027; MOL.19981007.0028; MOL.19981007.0029; MOL.19981007.0030; MOL.19981007.0031; MOL.19981007.0032.
153849	DOE 2001	DOE (U.S. Department of Energy) 2001. *Yucca Mountain Science and Engineering Report.* DOE/RW-0539. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0272.

Appendix F

Human Health Impacts Primer and Details for Estimating Health Impacts to Workers from Yucca Mountain Repository Operations

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APPENDIX F. HUMAN HEALTH IMPACTS PRIMER AND DETAILS FOR ESTIMATING HEALTH IMPACTS TO WORKERS FROM YUCCA MOUNTAIN REPOSITORY OPERATIONS

Section F.1 of this appendix contains information that supports the estimates of human health and safety impacts in this environmental impact statement (EIS). Specifically, Section F.1 is a primer that explains the natures of radiation and toxic materials, where radiation comes from in the context of the radiological impacts discussed in this EIS, how radiation interacts with the human body to produce health impacts, and how toxic materials interact with the body to produce health impacts. The remainder of the appendix discusses the methodology that was used to estimate worker health impacts and the input data to the analysis, and presents the detailed results of the analysis of worker health impacts.

Section F.2 discusses the methodology and data that the U.S. Department of Energy (DOE) used to estimate worker health and safety impacts for the Proposed Action. It also discusses the detailed results of the impact analysis.

Section F.3 discusses the methodologies and data that DOE used to estimate worker health and safety impacts for Inventory Modules 1 and 2. It also discusses the detailed results of the impact analysis.

Section F.4 discusses the methodology and data that DOE used to estimate worker health and safety impacts for retrieval, should such action become necessary. In addition, it discusses the detailed results from the impact analysis.

Radiological impacts to the public from operations at the Yucca Mountain site could result from release of naturally occurring radon-222 and its decay products in the ventilation exhaust from the subsurface repository operations. The methodology and input data used in the estimates of radiological dose to the public are presented in Appendix G, Air Quality. Outside of the radiation primer, health impacts to the public are not treated in this appendix.

F.1 Human Health Impacts from Exposure to Radioactive and Toxic Materials

This section introduces the concepts of human health impacts as a result of exposure to radiation and potentially toxic materials.

F.1.1 RADIATION AND HUMAN HEALTH

F.1.1.1 Radiation

Radiation is the emission and propagation of energy through space or through a material in the form of waves or bundles of energy called photons, or in the form of high-energy subatomic particles. Radiation generally results from atomic or subatomic processes that occur naturally. The most common kind of radiation is *electromagnetic radiation*, which is transmitted as photons. Electromagnetic radiation is emitted over a range of wavelengths and energies. We are most commonly aware of visible light, which is part of the spectrum of electromagnetic radiation. Radiation of longer wavelengths and lower energy includes infrared radiation, which heats material when the material and the radiation interact, and radio waves. Electromagnetic radiation of shorter wavelengths and higher energy (which are more penetrating) includes ultraviolet radiation, which causes sunburn, X-rays, and gamma radiation.

RADIATION

Radiation occurs on Earth in many forms, either naturally or as the result of human activities. Natural forms include light, heat from the sun, and the decay of unstable radioactive elements in the Earth and the environment. Some elements that exist naturally in the human body and in the environment are radioactive and emit ionizing radiation. For example, one of the naturally occurring isotopes of potassium (essential for health) is radioactive. In addition, isotopes of the naturally occurring uranium and thorium decay series are widespread in the human environment. Human activities have also led to sources of ionizing radiation for various uses, such as diagnostic and therapeutic medicine and nondestructive testing of pipes and welds. Nuclear power generation produces ionizing radiation as well as radioactive materials, which undergo radioactive decay and can continue to emit ionizing radiation for long periods of time.

Ionizing radiation is radiation that has sufficient energy to displace electrons from atoms or molecules to create ions. It can be electromagnetic (for example, X-rays or gamma radiation) or subatomic particles (for example, alpha and beta radiation). The ions have the ability to interact with other atoms or molecules; in biological systems, this interaction can cause damage in the tissue or organism.

F.1.1.2 Radioactivity, Ionizing Radiation, Radioactive Decay, and Fission

Radioactivity is the property or characteristic of an unstable atom to undergo spontaneous transformation (to *disintegrate* or *decay*) with the emission of energy as radiation. Usually the emitted radiation is ionizing radiation. The result of the process, called *radioactive decay*, is the transformation of an unstable atom (a *radionuclide*) into a different atom, accompanied by the release of energy (as radiation) as the atom reaches a more stable, lower energy configuration.

Radioactive decay produces three main types of ionizing radiation—alpha particles, beta particles, and gamma or X-rays—but our senses cannot detect them. These types of ionizing radiation can have different characteristics and levels of energy and, thus, varying abilities to penetrate and interact with atoms in the human body. Because each type has different characteristics, each requires different amounts of material to stop (shield) the radiation. Alpha particles are the least penetrating and can be stopped by a thin layer of material such as a single sheet of paper. However, if radioactive atoms (called radionuclides) emit alpha particles in the body when they decay, there is a concentrated deposition of energy near the point where the radioactive decay occurs. Shielding for beta particles requires thicker layers of material such as several reams of paper or several inches of wood or water. Shielding from gamma rays, which are highly penetrating, requires very thick material such as several inches to several feet of heavy material (for example, concrete or lead). Deposition of the energy by gamma rays is dispersed across the body in contrast to the local energy deposition by an alpha particle. In fact, some gamma radiation will pass through the body without interacting with it.

In a nuclear reactor, heavy atoms such as uranium and plutonium can undergo another process, called *fission*, after the absorption of a subatomic particle (usually a neutron). In fission, a heavy atom splits into two lighter atoms and releases energy in the form of radiation and the kinetic energy of the two new lighter atoms. The new lighter atoms are called fission products. The fission products are usually unstable and undergo radioactive decay to reach a more stable state.

Some of the heavy atoms might not fission after absorbing a subatomic particle. Rather, a new nucleus is formed that tends to be unstable (like fission products) and undergo radioactive decay.

The radioactive decay of fission products and unstable heavy atoms is the source of the radiation from spent nuclear fuel and high-level radioactive waste that makes these materials hazardous in terms of potential human health impacts.

F.1.1.3 Exposure to Radiation and Radiation Dose

Radiation that originates outside an individual's body is called *external* or *direct radiation*. Such radiation can come from an X-ray machine or from *radioactive materials* (materials or substances that contain radionuclides), such as radioactive waste or radionuclides in soil. *Internal radiation* originates inside a person's body following intake of radioactive material or radionuclides through ingestion or inhalation. Once in the body, the fate of a radioactive material is determined by its chemical behavior and how it is metabolized. If the material is soluble, it might be dissolved in bodily fluids and be transported to and deposited in various body organs; if it is insoluble, it might move rapidly through the gastrointestinal tract or be deposited in the lungs.

Exposure to ionizing radiation is expressed in terms of *absorbed dose,* which is the amount of energy imparted to matter per unit mass. Often simply called *dose*, it is a fundamental concept in measuring and quantifying the effects of exposure to radiation. The unit of absorbed dose is the *rad*. The different types of radiation mentioned above have different effects in damaging the cells of biological systems. *Dose equivalent* is a concept that considers (1) the absorbed dose and (2) the relative effectiveness of the type of ionizing radiation in damaging biological systems, using a radiation-specific quality factor. The unit of dose equivalent is the *rem*. In quantifying the effects of radiation on humans, other types of concepts are also used. The concept of *effective dose equivalent* is used to quantify effects of radionuclides in the body. It involves estimating the susceptibility of the different tissue in the body to radiation to produce a tissue-specific weighting factor. The weighting factor is based on the susceptibility of that tissue to cancer. The sum of the products of each affected tissue's estimated dose equivalent multiplied by its specific weighting factor is the *effective dose equivalent*. The potential effects from a one-time ingestion or inhalation of radioactive material are calculated over a period of 50 years to account for radionuclides that have long half-lives and long residence time in the body. The result is called the *committed effective dose equivalent*. The unit of effective dose equivalent is also the *rem*. *Total effective dose equivalent* is the sum of the committed effective dose equivalent from radionuclides in the body plus the dose equivalent from radiation sources external to the body (also in rem). All estimates of dose presented in this environmental impact statement, unless specifically noted as something else, are total effective dose equivalents, which are quantified in terms of rem or millirem (which is one one-thousandth of a rem).

More detailed information on the concepts of radiation dose and dose equivalent are presented in publications of the National Council on Radiation Protection and Measurements (DIRS 101857-NCRP 1993, p. 16-25) and the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, p. 4-11). The DOE implementation guide for occupational exposure assessment (DIRS 138429-DOE 1998, pp. 3 to 11) also provides additional information.

The factors used to convert estimates of radionuclide intake (by inhalation or ingestion) to dose are called *dose conversion factors*. The National Council on Radiation Protection and Measurements and Federal agencies such

FISSION

Fission is the process whereby a large nucleus (for example, uranium-235) absorbs a neutron, becomes unstable, and splits into two fragments, resulting in the release of large amounts of energy per unit of mass. Each fission releases an average of two or three neutrons that can go on to produce fissions in nearby nuclei. If one or more of the released neutrons on the average causes additional fissions, the process keeps repeating. The result is a self-sustaining chain reaction and a condition called criticality. When the energy released in fission is controlled (as in a nuclear reactor), it can be used for various benefits such as to propel submarines or to provide electricity that can light and heat homes.

as the U.S. Environmental Protection Agency publish these factors (DIRS 101882 and 101883-NCRP 1996, all; DIRS 107684-Eckerman and Ryman 1993, all; DIRS 101069-Eckerman, Wolbarst, and Richardson 1988, all). They are based on original recommendations of the International Commission on Radiological Protection (DIRS 101075-ICRP 1977, all).

The radiation dose to an individual or to a group of people can be expressed as the total dose received or as a dose rate, which is dose per unit time (usually an hour or a year).

Collective dose is the total dose to an exposed population. *Person-rem* is the unit of collective dose. Collective dose is calculated by summing the individual dose to each member of a population. For example, if 100 workers each received 0.1 rem, then the collective dose would be 10 person-rem (100 × 0.1 rem).

F.1.1.4 Background Radiation from Natural Sources

Nationwide, on average, members of the public are exposed to approximately 360 millirem per year from natural and manmade sources (DIRS 101896-Gotchy 1987, p. 53). Figure F-1 shows the relative contributions by radiation sources to people living in the United States (DIRS 101896-Gotchy 1987, p. 55).

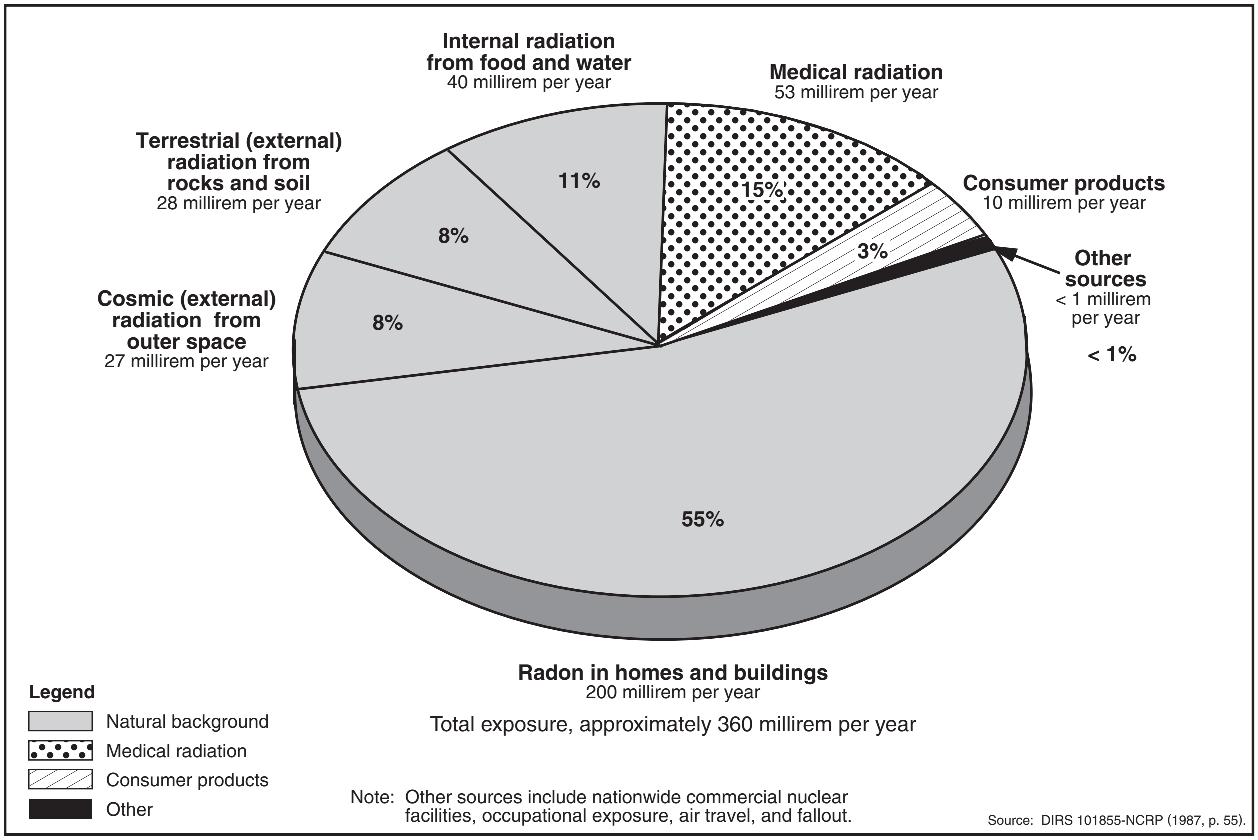

Figure F-1. Sources of radiation exposure.

The estimated average annual dose rate from natural sources is only about 300 millirem per year. This represents about 80 percent of the annual dose received by an average member of the U.S. public. The largest natural sources are radon-222 and its radioactive decay products in homes and buildings, which contribute about 200 millirem per year. Additional natural sources include radioactive material in the Earth (primarily the uranium and thorium decay series, and potassium-40) and cosmic rays from space filtered through the atmosphere. With respect to exposures resulting from human activities, medical exposure accounts for 15 percent of the annual dose, and the combined doses from weapons testing fallout, consumer and industrial products, and air travel (cosmic radiation) account for the remaining 3 percent of the total annual dose. Nuclear fuel cycle facilities contribute less than 0.1 percent (0.005 millirem per year per person) of the total dose (DIRS 101896-Gotchy 1987, pp. 53 to 55).

F.1.1.5 Impacts to Human Health from Exposure to Radiation

Exposures to radiation or radionuclides are often categorized as being either acute or chronic. Acute exposures occur over a short period. Chronic exposures occur over longer periods (months to years); they are usually continuous over the period, even though the dose rate might vary. For a given dose of radiation, chronic radiation exposure is usually less harmful to the body than an acute exposure because the dose rate (dose per unit time, such as rem per hour) is lower, providing more opportunity for the body to repair the damaged cells (DIRS 101836-ICRP 1991, p. 107).

Acute Exposures at High Dose Rates

Exposure to high levels of radiation at high dose rates over a short period, typically 24 hours or less, can result in acute radiation effects, called *radiation sickness*. If the dose is sufficiently high, death is the eventual result of radiation sickness. At lower doses, recovery can occur, depending on the dose rate and the extent of medical intervention. External (rather than internal) exposures are generally of most concern during a high dose rate, acute exposure event. In such a situation, the biological effects depend more on absorbed dose received than on dose equivalent (DIRS 155674-Hall 1978, p. 106-107).

For external exposures, minor changes in blood characteristics might occur at doses in the range of 25 to 50 rad. The external symptoms of radiation sickness begin to appear when exposures are about 100 rads or greater. Symptoms can include anorexia, nausea, and vomiting. More severe symptoms occur at higher doses and can include death at doses higher than 200 to 300 rad of total body irradiation, depending on the level of medical treatment received. Information on the effects on humans of acute exposures can be obtained from studies of the survivors of the Hiroshima and Nagasaki bombings during World War II and from studies following a number of acute external exposure events (DIRS 102185-Mettler and Moseley 1985, pp. 276-280).

Other effects can follow acute exposures to specific portions of the body. Temporary sterility in men and women has been observed following irradiation of the gonads to doses in the tens to hundreds of rads. Erythema (reddening of the skin) can occur when the skin is exposed to high doses of low-energy radiation (DIRS 108074-Cember 1983, pp. 181-184). In patients treated with external radiation beams for cancer therapy, pulmonary fibrosis or other lung disorders can occur.

As noted above, acute exposures have occurred following detonations of nuclear weapons, both in wartime and during weapons testing, and in other events involving testing of nuclear materials. In addition, there is a potential for acute exposures in the event of an accident at an operating nuclear electric generating station, although Nuclear Regulatory Commission regulations require that the electric utilities design their stations such that these events are extremely unlikely. Such exposures could occur only if there were a highly unlikely failure of the containment vessel surrounding the nuclear reactor and a large release of fission products from the generating station following an accident.

In contrast, accidents during the shipment of spent nuclear fuel or high-level radioactive waste do not have the potential to release sufficient fission products to lead to acute exposures that might immediately threaten the life of the surrounding public. This is because the fission product source term in the spent nuclear fuel would have decayed by a factor of 10,000 or more by the time DOE shipped the material to the proposed repository. Thus, there would not be sufficient energy generated by the fission products in the spent nuclear fuel being shipped to melt the fuel elements and vaporize fission products, as postulated for an accident at an operating nuclear electric generating station.

In the highly unlikely event of an accident during shipment of spent nuclear fuel that is severe enough to breach the shipping cask and rupture the contained spent nuclear fuel, there would be a potential to release fission products to the environment, as discussed in Chapter 6. Following such an event, the principal human exposure pathways would be inhalation or ingestion of released long-lived radioactive fission products. Such an intake of radioactivity could result in a continuing chronic exposure to an individual, but not an acute exposure. Continuing chronic exposures are discussed in the following subsection.

Exposures at Low Dose Rates Including Chronic Exposures

The radiation dose estimates discussed in this EIS are associated with exposure to radiation at low dose rates. Such exposures can be chronic (continuous or nearly continuous), such as those to workers during repository operation, or those to members of the public from the low concentrations of radon-222 and its decay products released in the exhaust from the repository. In some instances, exposures to low levels of radiation would be intermittent (for example, infrequent exposures to an individual from radiation emitted from shipping casks as they are transported). Cancer induction is the principal potential risk to human health from exposure to low levels of radiation. This cancer induction is a statistical process, however, in that exposure to radiation conveys only a chance of incurring cancer, not a certainty. Further, cancer induction in individuals can occur from other causes, such as exposure to chemical agents or natural causes.

Health effects other than fatal cancers can result from exposure to radiation. The International Commission on Radiological Protection suggested the use of detriment weighting factors that consider the curability rate of nonfatal cancers and the reduced quality of life associated with nonfatal cancers and possible hereditary effects (DIRS 101836-ICRP 1991, p. 22). These effects are very difficult to quantify because nonfatal cancers and hereditary effects can be induced from several other causes. Further, hereditary effects have not been demonstrated in humans as a result of exposure to radiation, even in the Japanese atomic bomb survivor population (DIRS 157315-Boice 1990, all). The risk of both of these life-detriment factors, taken together, is believed to be much smaller than the fatal cancer risk. In addition, the National Research Council Committee on Biological Effects of Ionizing Radiation has stated that cancer induction is the most important somatic effect (DIRS 153007-National Research Council 1980, pp. 2 and 136). While DOE recognizes the existence of health effects other than fatal cancers, DOE acknowledges that these effects are extremely difficult to quantify because of all the other factors in life that can cause these effects; accordingly, these effects are not included in the Final EIS. The Final EIS does present human health effects from exposure to radiation based on the potential for induction of fatal cancers.

There are no data that show a clear link between low levels of radiation exposure and cancer. Most of the data on induction of cancer by radiation comes from studying relatively small numbers of people who have received acute exposures to higher doses of radiation (more than 10 rem over a short period), such as atomic bomb survivors. Utilizing the information obtained at these higher exposure rates to estimate effects at low dose rates requires the assumption of a relationship between the overall exposure and the probability of a health effect. The approach generally used is called the *linear dose effect hypothesis*. This concept is shown in Figure F-2, which uses a hypothetical line to extrapolate dose effects at high dose rates to what might occur at low dose rates. It is obvious from the figure that more than one line or curve could be used to fit the data, all of which was obtained at dose rates above 10 rem. Because there is not a statistically significant number of observed effects in the low-dose-rate region, radiation protection organizations, such as the International Commission on Radiological Protection, have assumed a linear-no-threshold response (DIRS 101857-NCRP 1993, p. 112; DIRS 101836-ICRP 1991, p. 22). Under this

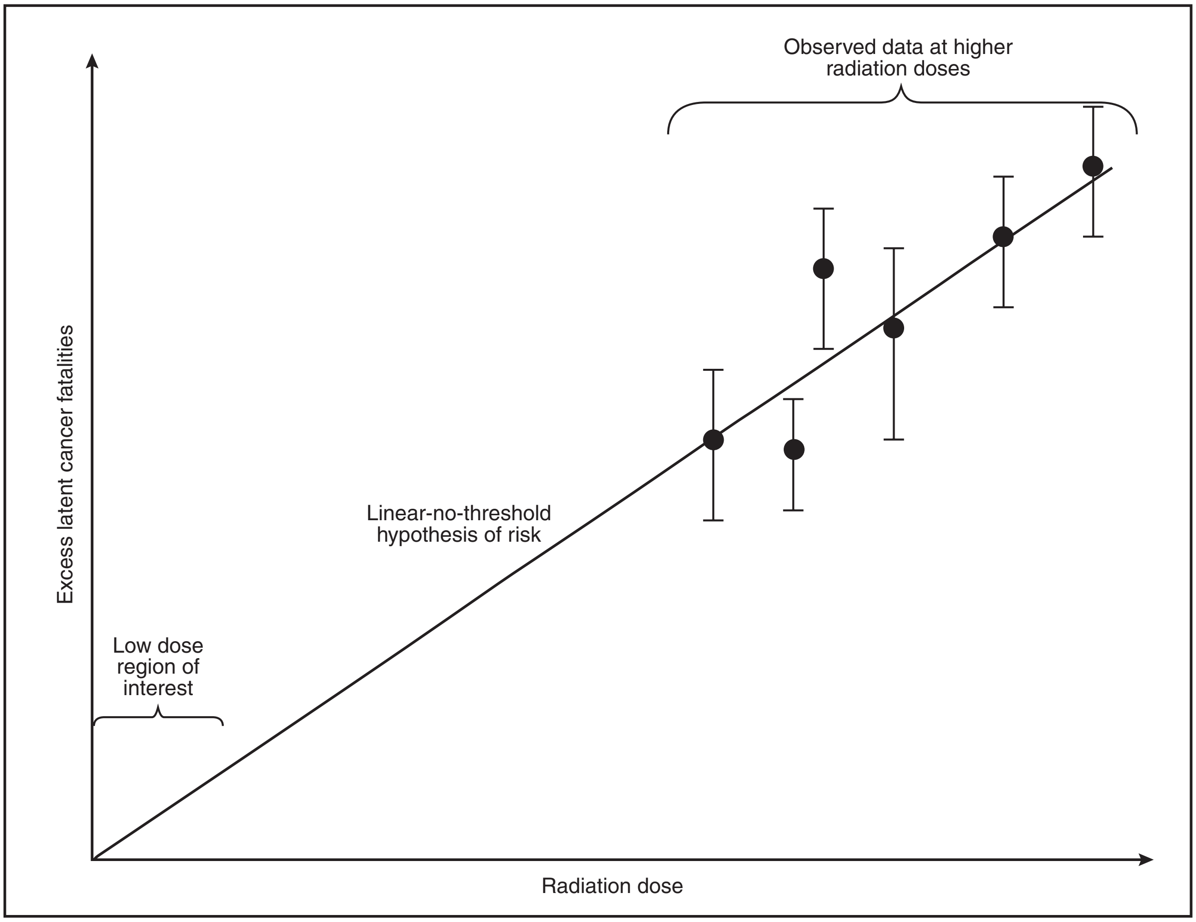

Figure F-2. Assumed linear hypothesis of radiation risks at low doses.

hypothesis, all radiation exposure, no matter how small, involves some risk for inducing cancer and risk increases in proportion to the received dose.

In this EIS, radiological health impacts are expressed as incremental changes in the number of expected fatal cancers (latent cancer fatalities) for the offsite public and for repository workers. Because of the uncertainties in dose response in the low-dose-rate region, the impact estimates provide a general indication of possible health impacts (the potential number of induced cancers) but should not be interpreted as the exact number of induced cancers or as an indication of the individuals in whom cancers might be induced.

Factors Used in this EIS To Convert Accumulated Doses to Health Effects

The factors used to estimate potential health impacts from radiation exposures at low dose rates are based on the dose-to-health-effects conversion factors recommended by the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, p. 22). The Commission estimated that, for the general population, a collective dose of 1 person-rem could yield about 0.0005 excess latent cancer fatality in the exposed population. Because young children are more sensitive to radiation than adults, and because children make up a large part of the general population, the risk conversion factor for the general population is greater than that for a population that includes only workers. Thus, a separate, smaller dose-to-risk conversion factor was recommended for workers (only people older than 18 were considered). The risk factor for workers recommended by the National Council on Radiation Protection and Measurements is 0.0004 excess latent cancer fatality per rem of population exposure (DIRS 101857-NCRP 1993, p. 3).

These concepts can be used to estimate the effects of exposing a population to radiation. For example, if each of 100,000 people was exposed only to background radiation (0.3 rem per year), 15 latent cancer fatalities would be estimated to occur as a result of 1 year of exposure (100,000 persons multiplied by 0.3 rem per year multiplied by 0.0005 latent cancer fatality per person-rem equals 15 latent cancer fatalities per year).

Calculations of the number of latent cancer fatalities associated with radiation exposure normally do not yield whole numbers and, especially in environmental applications, can yield numbers less than 1.0. For example, if each of 100,000 people was exposed to a total dose of 1 millirem (0.001 rem), the population dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons multiplied by 0.001 rem multiplied by 0.0005 latent cancer fatality per person-rem equals 0.05 latent cancer fatality).

The average number of deaths that would result if the same exposure situation applied to many different groups of 100,000 people is 0.05 for each such group. In most groups, nobody (zero people) would incur a latent cancer fatality from the 1-millirem dose to each member of the group. In a small fraction of the groups, one latent fatal cancer would result; in exceptionally few groups, two or more latent fatal cancers would occur. The average number of deaths over all the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 is 0.25). The most likely outcome is no latent cancer fatalities in these different groups.

The same concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation of 0.3 rem per year over a lifetime. The corresponding likelihood that an individual would experience a radiation-induced latent cancer fatality in that individual's 70-year lifetime is:

$$\text{Latent cancer fatality} = 1 \text{ person} \times 0.3 \text{ rem per year} \times 70 \text{ years} \times 0.0005 \text{ latent cancer fatality per person-rem} = 0.011 \text{ latent cancer fatality.}$$

This result must be interpreted in a statistical sense; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1-percent chance that the individual would incur a latent fatal cancer over a 70-year lifetime.

Uncertainty in the Risk Factors for Estimating Health Effects from Low Dose Rate Exposures

The National Council on Radiation Protection and Measurements has stated, "This work indicates that given the sources of uncertainties considered here, together with an allowance for unspecified uncertainties, the values for the lifetime risk can range from about one-fourth or so to about twice the nominal values" (DIRS 101884-NCRP 1997, p. 75). These uncertainties are due, in part, to the fact that the epidemiological studies have been unable to demonstrate that adverse health effects have occurred in individuals exposed to small chronic doses of radiation (less than 10 rem per year) over many years, and to the fact that the extent to which cellular repair mechanisms reduce the likelihood of cancers is unknown. Therefore, the uncertainties indicate that the values used in this EIS probably overestimate the impacts that could occur.

The Environmental Protection Agency recently published an age-specific risk factor of 5.75 chances in 10 million per millirem for fatal cancer (DIRS 153733-EPA 2000, Table 7.3, p. 179). However, DOE currently uses the value of 5.0 and 4.0 chances in 10 million per millirem for fatal cancer for members of the public and workers, respectively, as recommended by the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, p. 22). When recommending these risk factors, the International Commission on Radiological Protection also expressed the desirability, for purposes of radiation protection, of using the same nominal risk factors for both men and women and for a representative population with wide ranges in age. The Commission stated that although there are differences between the sexes and populations of different age-specific mortality rates, these differences are not so large as to necessitate the use of different nominal risk factors. However, the higher risk factor for members of the public compared to that recommended for workers accounts for the fact that children comprise a relatively large part of the population and are more sensitive to the effects of radiation (cancer induction) than adults. Although the embryo-fetus is more radiosensitive (with a radiation risk factor about two times that for the whole population), it is protected by the body of the mother and comprises a small part of the overall population. Pregnant women are not unduly radiosensitive, especially to low levels of radiation.

Both the Environmental Protection Agency and DOE recognize that there are large uncertainties associated with these risk factors, as expressed by the National Council on Radiation Protection and Measurements comment on the result of their uncertainty analysis in the risk coefficients that ". . . show a range (90 percent confidence intervals) of uncertainty values for the lifetime risk for both a population of all ages and an adult worker population from about a factor of 2.5 to 3 below and above the 50th percentile value" (DIRS 101884-NCRP 1997, p. 74). DOE believes that the 15-percent difference in these risk factors is well within other uncertainties and would provide little additional information to the decisionmaking process that this document informs.

Perspectives on Risk

While the risk factors cited above are useful for calculations, comparing them to other risks helps to interpret their meaning. For example, according to statistics published by the Centers for Disease Control, during 1995 the death rate due to cancer in Nevada was 202 cancer deaths per 100,000 persons. The death rate from all causes during that same year was 828 deaths per 100,000; therefore, cancer was responsible for 24 percent of deaths during 1998 (DIRS 153066-Murphy 2000, p. 83).

The long-term risk from exposure to radiation can be placed in perspective by comparison to other risks that are encountered on a daily basis. One method for comparison is the *Loss of Life Expectancy*, which is an estimate of the average number of days of life lost for a given risk factor for a population.

Table F-1 lists Loss of Life Expectancy values for a variety of activities and circumstances. At the bottom of the table is the estimate of Loss of Life Expectancy for several different radiation exposure scenarios.

As discussed in the preceding section, the risk factor (and hence the Loss of Life Expectancy) for radiation exposure is based on an assumption that all radiation exposure carries some risk, even though that assumption has not been proven and might overestimate the true risk from low-level exposure.

F.1.1.6 Exposures from Naturally Occurring Radionuclides in the Subsurface Environment

The estimates of worker doses from inhalation of radon-222 and its decay products while in the subsurface environment and from the ambient radiation fields in the subsurface environment were based on measurements taken in the existing Exploratory Studies Facility drifts. The measurements and the annual dose rates derived from them are discussed below.

Table F-1. Loss of Life Expectancy for causes of death for average citizens of the United States.[a]

Risk factor	Loss of life expectancy (days)
Disease	
Cardiovascular diseases	2,043
Cancer – all types	1,247
Chronic pulmonary	164
Pneumonia	103
Diabetes	82
Tuberculosis	4.7
Influenza	2.3
Accidents	
Motor vehicle accidents	207
Homicide	93
Accidents at home	74
Accidents at work	60
Agriculture	320
Construction	227
Services	27
Radiation exposure	
Lifetime of continuous exposure (100 millirem per year)	15[b]
Single acute exposure of 1 millirem	0.002[b]
Single acute exposure of 1,000 millirem	2.3[b]

a. Tabulated by DIRS 155797-Cohen (1991, Table 3, p. 319).
b. Adapted from methodology presented by DIRS 155797-Cohen (1991, all).

Annual Dose Rate for Subsurface Facility Worker from Inhalation of Radon-222

The annual dose rate for a subsurface worker from inhalation of radon-222 and its decay products was estimated using information developed from radon concentration observations made in the Exploratory Studies Facility subsurface areas during site characterization and subsequent analyses of this data. Two reports (DIRS 152046-DOE 2000, all; DIRS 154176-CRWMS M&O 2000, all) have significantly expanded the available information on radon-222 flux into the repository, radon concentrations in the repository atmosphere, and radon releases from the repository. Additional information on radon release is in Appendix G, Section G.2.3.1.

Recent investigations of radon levels in the repository have led to estimates of radon exposure in Working Level units (DIRS 154176-CRWMS M&O 2000, Attachment 4). The Working Level is the common unit for expressing radon decay product exposure rates. The Working Level was originally developed for use in uranium mines but now is used for environmental exposures as well. Numerically, the Working Level is any combination of short-lived decay products in 1 liter of air that will result in the emission of 1.3×10^5 million electron volts of potential alpha energy. When radon is in complete equilibrium with its short-lived decay products, one Working Level equals 100 picocuries per liter (DIRS 153691-NCRP 1988, p. 17); that is, 100 picocuries per liter each of radon-222 and short-lived decay products polonium-218, lead-214, bismuth-214, and polonium-214. The advantage of the Working Level concept is that different equilibrium levels and different concentrations of radon decay products can be expressed and compared in a common unit. Differences in the activity concentrations between radon-222 and the short-lived decay products are considered using an equilibrium factor (DIRS 103279-ICRP 1994, p. 4). The degree of equilibrium is a critical factor for estimating inhalation exposure and is as important as the radon concentration itself (DIRS 153691-NCRP 1998, p. 19). The Working Level unit considers this factor.

The exposure of workers can be expressed in units of Working-Level Months, which is an exposure rate of 1 Working Level for a working month of 170 hours (DIRS 153691-NCRP 1988, p. 17). Working-Level Months can be converted to more familiar dose units of millirem or rem using a conversion factor of 0.5 rem (500 millirem) per Working-Level Month for inhalation of radon decay products by workers (DIRS 103279-ICRP 1994, p. 24). This dose conversion factor corresponds to 0.029 millirem per picocurie per liter per hour for radon decay products in complete equilibrium with the radon-222 parent (DIRS 103279-ICRP 1994, p. 5).

Average hourly dose rates were estimated for workers in the access mains and ramps, the emplacement drifts and similar 5.5-meter- (18-foot)- diameter drifts, and the overall repository with and without concrete liners, which would reduce the radon flux into the repository. The 5.5-meter drifts would not have concrete liners. These would be the main areas of the repository occupied by workers. Hourly dose rate estimates were developed for involved and noninvolved workers based on their likely work locations, which would also depend on the project phase or activity. Estimated hourly dose rates for involved and noninvolved workers, as well as estimates of the annual dose from radon based on 2,000 hours of occupational exposure in the repository, are listed in Table F-2.

Table F-2. Estimated dose rates to subsurface workers from inhalation of radon.[a]

Project phase and activity	Hourly dose rate (millirem per hour)	Annual dose rate (millirem per year)[b]
Construction		
Involved worker	0.10	200
Noninvolved worker	0.03	60
Operation and Monitoring		
Development		
Involved worker	0.10	200
Noninvolved worker	0.03	60
Emplacement		
Involved worker	0.06	120
Noninvolved worker	0.010	20
Monitoring		
Involved worker	0.050	100
Noninvolved worker	0.010	20
Closure		
Involved worker	0.010	20
Noninvolved worker	0.010	20

a. Numbers are rounded to two significant figures.
b. Based on 2,000 hours per year of occupational exposure in the repository.

In general, workers spending time in subsurface areas without concrete liners and with ventilation flow would have the highest exposures to radon and its decay products. These would be the involved workers during the construction phase and during the drift development period of the operation and monitoring phase. Noninvolved workers would spend more time in the access mains and ramps, with correspondingly less exposure from inhalation of radon decay products. By the end of the development period, all concrete liners would be in place, and exposures to radon decay products would be lower for workers during monitoring and closure. Involved workers during the monitoring period would receive moderate doses because they would be in all areas of the repository, including areas with exhaust from unlined drifts [such as emplacement drifts and other 5.5-meter (18-foot)-diameter drifts].

Annual Dose for Subsurface Facility Worker from Ambient External Radiation in Drifts

Workers in the subsurface facility would be exposed to external radiation from naturally occurring radionuclides in the rock. Measured exposure rates for the subsurface facility ranged from 0.014 to 0.038

millirem per hour (DIRS 104544-CRWMS M&O 1999, p. 12). As for inhalation dose estimates, the analysis assumed an underground exposure time of 2,000 hours per year. The estimated dose range to a worker in the repository from ambient external radiation would be from 28 to 76 millirem per year, with the center of the range being 50 millirem per year. This central estimate was used in this appendix for calculating worker dose estimates from ambient external radiation.

F.1.2 EXPOSURE TO TOXIC OR HAZARDOUS MATERIALS

When certain natural or manmade materials or substances have harmful effects that are not random or do not occur solely at the site of contact, the materials or substances are described as toxic. Toxicology is the branch of science dealing with the toxic effects that chemicals or other substances might have on living organisms.

Chemicals can be toxic for many reasons, including their ability to cause cancer, to harm or destroy tissue or organs, or to harm body systems such as the reproductive, immune, blood-forming, or nervous systems. The following list provides examples of substances that can be toxic:

- Carcinogens, which are substances known to cause cancer in humans or in animals. If cancers have been observed in animals, they could occur in humans. Examples of generally accepted human carcinogens include asbestos, benzene, and vinyl chloride (DIRS 103672-Kamrin 1988, pp. 37 and 38 and Chapter 6).

- Chemicals that controlled studies have shown to cause a harmful or fatal effect. Examples include metals such as cadmium, lead, and mercury; strong acids such as nitric acid and sulfuric acid; some welding fumes; coal dust; sulfur dioxide; and some solvents.

- Some biological materials, including various body fluids and tissues and infectious agents, are toxic.

Even though chemicals might be toxic, many factors influence whether or not a particular substance has a toxic effect on humans. These factors include (1) the amount of the substance with which the person comes in contact, (2) whether the person inhales or ingests a relatively large amount of the substance in a short time (acute exposure) or repeatedly ingests or inhales a relatively small amount over a longer time (chronic exposure), and (3) the period of time over which the exposure occurs.

Scientists determine a substance's toxic effect (or toxicity) by performing controlled tests on animals. In addition to environmental and physical factors, these tests help establish three other important factors for measuring toxicity—dose-response relationship, threshold concept, and margin of safety. The dose-response relationship relates the percentage of test animals that experience observable toxic effects to the doses administered. After the administration of an initial dose, the dose is increased or decreased until, at the upper end, all animals are affected and, at the lower end, no animals are affected. Thus, there is a threshold concentration below which there is no effect. The margin of safety is an arbitrary separation between the highest concentration or exposure level that produces no adverse effect in a test animal species and the concentration or exposure level designated safe for humans. There is no universal margin of safety. For some chemicals, a small margin of safety is sufficient; others require a larger margin.

Two substances in the rock at Yucca Mountain, crystalline silica and erionite, are of concern as potentially toxic or hazardous materials. Both of these naturally occurring compounds occur in the parent rock at the repository site, and excavation activities could encounter them. The following paragraphs contain additional information on these.

Crystalline Silica

Crystalline silica is a naturally occurring, highly structured form of silica (silicon dioxide, SiO_2). Because it can occur in several different forms, including quartz, cristobalite, and tridymite, it is called a *polymorph*. These three forms occur in the welded tuff parent rock at Yucca Mountain (DIRS 104494-CRWMS M&O 1998, p. 25). Crystalline silica is a known causative agent for *silicosis*, a destructive lung condition caused by deposition of particulate matter in the lungs and characterized by scarring of lung tissue. It is contracted by prolonged exposure to high levels of respirable silica dust or an acute exposure to even higher levels of respirable silica dust (DIRS 103243-EPA 1996, Chapter 8). Accordingly, DOE considers worker inhalation of respirable crystalline silica dust particles to be hazardous to worker health. Current standards for crystalline silica have been established to prevent silicosis in workers.

Cristobalite and tridymite have a lower exposure limit than does quartz. The limits for these forms of silica include the Permissible Exposure Limits established by the Occupational Safety and Health Administration and the Threshold Limit Value defined by the American Conference of Governmental Industrial Hygienists. The Occupational Safety and Health Administration Permissible Exposure Limit for cristobalite or tridymite is 50 micrograms per cubic meter averaged over a 10-hour work shift. The American Conference of Governmental Industrial Hygienists Threshold Limit Value is also 50 micrograms per cubic meter, but it is averaged over an 8-hour work shift (DIRS 103674-NJDHSS 1996, all). Thus, the two limits are essentially the same. In accordance with DOE Order 440.1A (DIRS 138429-DOE 1998, p. 5), the more restrictive value provided by the American Conference of Governmental Industrial Hygienists will be applied. In addition, the National Institute for Occupational Safety and Health has established Immediately-Dangerous-to-Life-and-Health concentration limits at levels of 50,000 and 25,000 micrograms per cubic meter for quartz and cristobalite, respectively (DIRS 147940-NIOSH 1996, p. 2). These limits are based on the maximum airborne concentrations an individual could tolerate for 30 minutes without suffering symptoms that could impair escape from the contaminated area or irreversible acute health effects.

There is also evidence that silica may be a carcinogen. The International Agency for Research on Cancer has classified crystalline silica and cristobalite as a Class I (known) carcinogen (DIRS 100046-IARC 1997, pp. 205 to 210). The National Institute for Occupational Safety and Health considers crystalline silica to be a potential carcinogen, as defined by the Occupational Safety and Health Administration's carcinogen policy (29 CFR Part 1990). The National Institute for Occupational Safety and Health is reviewing data on carcinogenicity, which could result in a revised limit for crystalline silica. The Environmental Protection Agency has noted an increase in cancer risk to humans who have already developed the adverse noncancer effects of silicosis, but the cancer risk to otherwise healthy individuals is not clear (DIRS 103243-EPA 1996, pp. 1 to 5).

Because there are no specific limits for exposure of members of the public to crystalline silica, this analysis used a comparative benchmark of 10 micrograms per cubic meter, based on a cumulative lifetime exposure limit of 1,000 micrograms per (cubic meter multiplied by years). At this level, an Environmental Protection Agency health assessment has stated that there is a less than 1-percent chance of silicosis (DIRS 103243-EPA 1996, Chapter 1, p. 5, and Chapter 7, p. 5). Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter, which was rounded down to 10 micrograms per cubic meter to establish the benchmark. Appendix G, Section G.1 contains additional information on public exposure to crystalline silica.

Samples of the welded tuff parent rock from four boreholes at Yucca Mountain have an average quartz content of 15.7 percent, an average cristobalite content of 16.3 percent, and an average tridymite content of 3.5 percent (DIRS 104494-CRWMS M&O 1998, p. I-1). Worker protection during excavation in the subsurface would be based on the more restrictive Threshold Limit Value for cristobalite. The analysis assumed that the parent rock and dust would have a cristobalite content of 28 percent, which is the higher end of the concentration range reported in DIRS 104523-CRWMS M&O (1999, p. 4-81). Thus, the assumed percentage of cristobalite in dust probably overestimated the airborne cristobalite concentration. Also, studies of both ambient and occupational airborne crystalline silica have shown that most of the airborne crystalline silica is coarse and not respirable (greater than 5 micrometers aerodynamic diameter), and the larger particles deposit rapidly on the surface (DIRS 103243-EPA 1996, p. 3-26).

Erionite

Erionite is a natural fibrous zeolite that occurs in the rock layers below the proposed repository level in the hollows of rhyolitic tuffs and in basalts. It might also occur in rock layers above the repository level but has not been found in those layers. Erionite is a rare tectosilicate zeolite with hexagonal symmetry that forms wool-like fibrous masses (with a maximum fiber length of about 50 microns, which is generally shorter than asbestos fibers) (DIRS 102057-HHS 1994, p. 134).

There are no specific limits for exposure to erionite. Descriptive studies have shown very high mortality from cancer [malignant mesothelioma, mainly of the pleura (a lung membrane)] in the population of three Turkish villages in Cappadocia where erionite is mined. The International Agency for Research on Cancer has indicated that these studies demonstrate the carcinogenicity of erionite to humans. The Agency classifies erionite as a Group 1 (known) carcinogen (DIRS 103278-IARC 1987, all).

Erionite could become a potential hazard during excavation of access tunnels to the lower block and to offset areas for all operating modes or during vertical boring operations necessary to excavate ventilation shafts. DOE does not expect to encounter erionite layers during the vertical boring operations, which would be through rock layers above known erionite layers, or during excavation of access tunnels to the lower block or offset Area 5, where any identified layers of erionite would likely be avoided (DIRS 104532-McKenzie 1998, all). In accordance with the Erionite Protocol (DIRS 104527-YMP 1995, all), a task-specific health and safety plan would be prepared before the start of boring operations to identify this material and prevent worker inhalation exposures from unconfined material.

The Los Alamos National Laboratory is studying the mineralogy and geochemistry of the deposition of erionite under authorization from the DOE Office of Science. Laboratory researchers are applying geochemical modeling so they can understand the factors responsible for the formation of zeolite assemblages in volcanic tuffs. The results of this modeling will be used to predict the distribution of erionite at Yucca Mountain and to assist in the planning of excavation operations so erionite layers are avoided.

F.1.3 EXPOSURE PATHWAYS

Four conditions must exist for there to be a pathway from the source of released radiological or toxic material to a person or population (DIRS 102174-Maheras and Thorne 1993, p. 1):

- A source term: The material released to the environment, including the amount of radioactivity (if any) or mass of material, the physical form (solid, liquid, gas), particle size distribution, and chemical form
- An environmental transport medium: Air, surface water, groundwater, or a food chain
- An exposure route: The method by which a person can come in contact with the material (for example, external exposure from contaminated ground, immersion in contaminated air or internal exposure from inhalation or ingestion of radioactive or toxic material)
- A human receptor: The person or persons potentially exposed; the level of exposure depends on such factors as location, duration of exposure, time spent outdoors, and dietary intake

These four elements define an exposure pathway. For example, one exposure scenario might involve release of contaminated gas from a stack (source term); transport via the airborne pathway (transport medium); external gamma exposure from the passing cloud (exposure route); and an onsite worker (human receptor). Another exposure scenario might involve a volatile organic compound as the source term, release to groundwater as the transport medium, ingestion of contaminated drinking water as the exposure route, and offsite members of the public as the human receptors. No matter which pathway the scenario involves, local factors such as water sources, agriculture, and weather patterns play roles in determining the importance of the pathway when assessing potential human health effects.

Worker exposure to crystalline silica (and possibly erionite) in the subsurface could occur from a rather unique exposure pathway. Mechanical drift excavation, shaft boring, and broken rock management activities could create airborne dust comprising a range of particles sizes. Dust particles smaller than 10 micrometers have little mass and inertia in comparison to their surface area; therefore, these small particles could remain suspended in dry air for long periods. Airborne dust concentrations could increase if the ventilation system recirculated the air or if airflow velocity in the subsurface facilities became high enough to entrain dust previously deposited on drift or equipment surfaces. As tunnel boring machines or road headers break the rock from the working face, water would be applied to wet both the working face and the broken rock to minimize airborne dust levels. Wet or dry dust scrubbers would capture dust that was not suppressed by the water sprays. To prevent air recirculation, which would lead to an increase of airborne dust loads, the fresh air intake and the exhaust air streams would be separated. Finally, the subsurface ventilation system would be designed and operated to control ambient air velocities to minimize dust reentrainment. If these engineering controls did not maintain dust concentrations below the Threshold Limit Value concentration, workers would have to wear respirators until engineering controls established habitable conditions.

F.2 Worker Human Health and Safety Impact Analysis for the Proposed Action Inventory

This section discusses the methodologies and data used to estimate industrial and radiological health and safety impacts to workers that would result from the construction, operation and monitoring, and closure of the Yucca Mountain Repository, as well as the detailed results from the impact calculations. Section F.2.1 describes the methods used to estimate impacts, Section F.2.2 contains tabulations of the detailed data used in the impact calculations and references to the data sources, and Section F.2.3 contains a detailed tabulation of results.

For members of the public, the EIS uses the analysis methods in Appendix G, Section G.2, to estimate radiation dose from radon-222 and crystalline silica released in the subsurface ventilation system exhaust. The radiation dose estimates were converted to estimates of human health impacts using the dose conversion factors discussed in Section F.1.1.5. These impacts are expressed as the probability of a latent cancer fatality for a maximally exposed individual and as the number of latent cancer fatalities among members of the public within about 80 kilometers (50 miles) for the Proposed Action, the retrieval contingency, and the inventory modules. The results are listed in Chapter 4, Section 4.1.7.

Health and safety impacts to workers have been estimated for two worker groups: involved workers and noninvolved workers. Involved workers are craft and operations personnel who would be directly involved in activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste material; monitoring of conditions and performance of the waste packages; and those directly involved in closure activities. Noninvolved workers are managerial, technical, supervisory, and administrative personnel who would not be directly involved in construction, excavation, operations, monitoring, and closure activities. The analysis did not consider project workers who would not be located at the repository site.

DOE considered two spent nuclear fuel packaging scenarios: (1) receipt in an uncanistered form, and (2) receipt in dual-purpose canisters. These two scenarios bound the impacts from packaging scenarios involving canistered forms.

Health and safety impacts to workers were ascertained to be largest for the uncanistered packaging scenarios in the Draft EIS (see Tables 4-32 and 4-33). Thus, the uncanistered scenarios bound the health and safety impacts to workers.

In this appendix, worker impacts are listed for the uncanistered and dual-purpose canister packaging scenarios. DOE analyzed each scenario under a higher-temperature repository operating mode and a range of lower-temperature operating mode scenarios. The lower-temperature scenarios evaluated conservative and realistic combinations of waste package spacing; commercial spent nuclear fuel aging and blending; use of derated packages; and ventilation operating parameters (method and duration). For the lower-temperature operating mode, DOE limited the analysis for dual-purpose canisters to the scenario with the longest ventilation period without aging. The results show that the combination of uncanistered packaging and lower-temperature operating scenarios would have the highest worker health and safety impacts.

Radiological health impacts to the public are independent of the spent nuclear fuel packaging scenarios. Thus, only one set of radiological health impacts to the public was developed and presented in Chapter 4.

F.2.1 METHODOLOGY FOR CALCULATING OCCUPATIONAL HEALTH AND SAFETY IMPACTS

To estimate the impacts to workers from industrial hazards common to the workplace, values for the full-time equivalent work years for each phase of the project were multiplied by the statistic (occurrence per 10,000 full-time equivalent work years) for the impact being considered. Values for the number of full-time equivalent workers for each phase of the project are listed in Section F.2.2.1. The statistics for industrial impacts for each of the phases are listed in Section F.2.2.2 for involved and noninvolved workers.

Two kinds of radiological health impacts to workers are provided in this EIS. The first is an estimate of the latent cancer fatalities to the worker group involved in a particular project phase. The second is the incremental increase in latent cancer fatality probability attributable to occupational radiation for a maximally exposed individual in the worker population for each project phase.

To calculate the expected number of worker latent cancer fatalities during a phase of the project, the collective dose to the worker group, in person-rem, was multiplied by a standard factor for converting the collective worker dose to projected latent cancer fatalities (see Section F.1.1.5). As discussed in Section F.1.1.5, the value of this factor for radiation workers is 0.0004 excess latent cancer fatality per person-rem of dose.

The collective dose for a particular phase of the operation is calculated as the product of the number of exposed full-time equivalent workers for the project phase (see Section F.2.2.1), the average dose over the exposure period, and the fraction of the working time that a worker is in an environment where there is a source of radiation exposure. Values for exposure rates for both involved and noninvolved workers are presented in Section F.2.2.3 as are the fractional occupancy factors. The calculation of collective dose to subsurface workers from exposure to the radiation emanating from the loaded waste packages is an exception. Collective worker doses from this source of exposure were calculated using the methodology described in Subsurface Engineering File, (DIRS 150941-CRWMS M&O 2000, Appendix G). Estimates of annual exposure rates for subsurface workers from radiation emanating from the waste packages are contained in Table G-5 of that document. Tables G-1 through G-4 of that document contain information that supports the annual exposure rates estimates in Table G-5.

To estimate the incremental increase in the likelihood of death from a latent cancer for the maximally exposed individual, the estimated dose to the maximally exposed worker was multiplied by the factor for converting radiation dose to latent cancers. The factor applied for workers was 0.0004 latent cancer fatality per rem, as discussed above and in Section F.1.1.5. Thus, if a person were to receive a dose of 1 rem, the incremental increase in the probability that person would suffer a latent cancer fatality is 1 in 2,500 or 0.0004.

To estimate the dose for a hypothetical maximally exposed individual, the analysis generally assumed that this individual would be exposed to the radiation fields over the entire duration of a project phase or for 50 years, whichever would be shorter (see Section F.2.2.3). Other sources of exposure while working underground would be ambient radiation coming from the radionuclides in the drift walls and from inhalation of radon-222 and its decay products. The radiation from the waste package is usually the dominant component when these three dose contributors are added. Doses for the maximally exposed subsurface worker were estimated by adding the three dose components because they would occur simultaneously.

F.2.2 DATA SOURCES AND TABULATIONS

F.2.2.1 Work Hours for the Repository Phases

Table F-3 lists the number of workers involved in the various repository phases in terms of full-time equivalent work years. Each full-time equivalent work year represents 2,000 work hours (the number of hours assumed for a normal work year). The sources of the values in the table are indicated by the table references and footnotes. The primary sources of the values are the surface and subsurface engineering files.

In estimating work hours for each of the phases, the duration of the phase is one of the important factors. The durations of the monitoring and closure phases are variable for the different designs analyzed. Values for the phase durations for each of the design cases are presented in the footnotes to Table F-3.

F.2.2.2 Workplace Health and Safety Statistics

The analysis selected health and safety statistics for three impact categories—total recordable cases, lost workday cases, and fatalities. Total recordable cases are occupational injuries or illnesses that result in:

- Fatalities, regardless of the time between the injury and death, or the length of the illness
- Lost workday cases, other than fatalities, that result in lost workdays
- Nonfatal cases without lost workdays that result in transfer to another job, termination of employment, medical treatment (other than first aid), loss of consciousness, or restriction of work or motion

Lost workday cases, which are described above, include cases that result in the loss of more than half a workday. These statistical categories, which have been standardized by the U.S. Department of Labor and the Bureau of Labor Statistics, must be reported annually by employers with 11 or more employees. Table F-4 summarizes the health and safety impact statistics used for this analysis.

Table F-4 cites three sets of statistics that were used to estimate total recordable cases and lost workday cases for workers during activities at the Yucca Mountain site. In addition, there is a fourth statistic related to the occupational fatality projections for the Yucca Mountain site activities. The source of information from which the sets of impact statistics were derived is discussed below. All of the statistics are based on DOE experience for similar types of activities and were derived from the DOE CAIRS

Table F-3. Estimated full-time equivalent worker years for repository phases[a] (page 1 of 2).

				Operating mode			
				Higher-temperature		Lower-temperature	
Phase	Subphase	Period	Worker group	UC[b]	DPC[c]	UC (range)	DPC[d]
Construction	Surface[e]	44 months	Involved	2,800	2,500	2,600 - 2,900	2,500
			Noninvolved	1,100	940	990 - 1,100	940
	Subsurface	5 years	Involved	2,700	2,700	2,700	2,700
			Noninvolved	560	560	560	560
	Solar power generating facility	6 years	Involved	76	76	76	76
			Noninvolved	26	26	26	26
	Aging facilities[f]	16 years	Involved	NA[g]	NA	1,300	NA
			Noninvolved	NA	NA	500	NA
	Construction subtotals			7,300	6,800	7,300 - 8,800	6,800
Operations	Surface handling	First 24 years	Involved	23,000	15,000	23,000 - 24,000	15,000
			Noninvolved	8,200	9,300	8,200	9,300
		Last 26 years (aging only)[h]	Involved	NA	NA	13,000	NA
			Noninvolved	NA	NA	4,400	NA
	Subsurface emplacement	First 24 years[i]	Involved	1,800	1,800	1,800 - 2,500	1,800
			Noninvolved	380	380	380 - 530	380
		Last 26 years (aging only)[j]	Involved	NA	NA	1,900	NA
			Noninvolved	NA	NA	420	NA
	Subsurface development	22 years[k]	Involved	6,200	6,200	6,600 - 7,500	6,600
			Noninvolved	2,000	2,000	2200	2,200
	Operations subtotals			4,2000	34,000	42,000 - 63,000	35,000
Monitoring	Surface facility decontamination	3 years	Involved	2,700	2,000	2,200 - 2,700	2,000
			Noninvolved	690	610	610 - 690	610
	Surface	Variable[l]	Involved	2,600	2,600	3,400 - 10,000	10,000
			Noninvolved	0	0	0	0
	Subsurface	Variable[m]	Involved	5,200	5,200	6,800 - 21,000	21,000
			Noninvolved	990	990	1,300 - 3,900	3,900
	Solar panel maintenance	Variable[n]	Involved	180	180	270 - 580	580
	Solar panel replacement	Every 20 years[o]	Involved	36	36	63 - 140	140
	Monitoring subtotals			12,000	12,000	15,000 - 39,000	38,000
Closure	Surface facilities	6 years	Involved	2,900	2,500	2,900	2,500
			Noninvolved	1,100	950	1,100	950
	Subsurface	Variable[p]	Involved	2,400	2,400	2,600 - 4,000	2,600
			Noninvolved	450	450	500 - 770	500
	Solar power generating facility	6 years	Involved	62	62	62	62
			Noninvolved	24	24	24	24
	Closure subtotals			6,900	6,400	7,100 - 8,800	6,700
Totals				***68,000***	***59,000***	***77,000 - 110,000***	***87,000***

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Table F-3. Estimated full-time equivalent worker years for repository phases[a] (page 2 of 2).

a. Sources: Derived from DIRS 152010-CRWMS M&O (2000, all); DIRS 150941-CRWMS M&O (2000, all); DIRS 155516-Williams (2001, all); DIRS 155515-Williams (2001, all); DIRS 153882-Griffith (2001, all); DIRS 154758-Lane (2000, all); DIRS 153958-Morton (2000, all).
b. UC = uncanistered packaging scenario.
c. DPC = dual-purpose canister packaging scenario.
d. Values are for the lower-temperature long-term ventilation scenario without aging, which would require the greatest number of worker-years for the dual-purpose canister packaging scenario among the lower-temperature scenarios.
e. For the aging and derated waste package scenarios, the analysis applied the ratios of total buildings size between the higher-temperature scenario and the aging and derated waste package scenarios to calculate worker-year values for surface construction in those scenarios. Those ratios are 0.94 for aging scenarios and 1.04 for the derated waste package scenario.
f. For aging scenarios, the analysis assumed that the worker-year values for construction of the surface aging facility would be four-sevenths of those for a 70,000-MTHM retrieval facility. The analysis further assumed that initial construction of one-eighth of the aging pads would occur over 2 years from 2008 to 2010, and that the remaining aging pads would be constructed over the next 14 years, as needed.
g. NA = not applicable.
h. For the last 26 years of surface handling for the aging scenarios, the scale of waste handling operations in the surface facilities would decrease because no more waste would be received. The analysis assumed that the annual number of workers would be one-half of that for the first 24 years.
i. For the derated waste package scenario, the analysis assumed that the ratio of the number of derated waste packages to the number of higher-temperature mode full-size packages (15,600 : 11,300, or 1.38) would apply to the number of involved and noninvolved workers emplacing those waste packages.
j. For the last 26 years of emplacement for the aging scenarios, while the emplacement rate would be substantially reduced, the analysis conservatively assumed no reduction in annual staffing levels.
k. Though the subsurface development period would remain 22 years, annual staffing would be increased to meet the additional excavation demands for the lower-temperature repository operating mode. For the aging scenarios, the development period could be longer, but the number of worker-years would be the same because the amount of excavation would be the same with or without aging.
l. Surface monitoring periods would extend from the end of surface decontamination to the beginning of closure: higher-temperature, 73 years; lower-temperature with long-term ventilation without aging, 297 years; lower-temperature with long-term ventilation with aging, 271 years; lower-temperature with maximum spacing without aging, 122 years; lower-temperature with maximum spacing with aging, 96 years. For scenarios with aging, monitoring and emplacement activities could overlap for part of the last 26 years of the 50-year aging emplacement period.
m. Subsurface monitoring periods would extend from the end of emplacement to the beginning of closure: higher-temperature, 76 years; lower-temperature with long-term ventilation without aging, 300 years; lower-temperature with long-term ventilation with aging, 274 years; lower-temperature with maximum spacing without aging, 125 years; lower-temperature with maximum spacing with aging, 99 years. For scenarios with aging, monitoring and emplacement activities could overlap for part of the last 26 years of the 50-year aging emplacement period.
n. Solar power facility operations would extend from the beginning of emplacement to the end of monitoring: higher-temperature, 100 years; lower-temperature with long-term ventilation, 324 years; lower-temperature with maximum spacing, 149 years.
o. Solar panels would require replacement every 20 years, involving about 9 worker-years per replacement (6 workers for 3 months for each of 6 arrays). Panels would be replaced 4 times for the 100-year higher-temperature mode operating-period, 16 times during the 324-year lower-temperature with long-term ventilation operating-period, and 7 times during the 149-year lower-temperature with maximum spacing operating-period.
p. Subsurface closure periods: Higher-temperature operating mode, 10 years; lower-temperature operating mode with long-term ventilation with or without aging and with natural ventilation, 11 years; lower-temperature operating mode with long-term ventilation with derated waste packages, 12 years; lower-temperature operating mode with maximum spacing, 17 years.

Table F-4. Health and safety statistics for estimating industrial safety impacts common to the workplace.

Phase	Total recordable cases incidents per 100 FTEs[a]		Lost workday cases per 100 FTEs		Fatalities per 100,000 FTEs (involved and noninvolved)[b]	Data set for TRCs and LWCs[c,d]
	Involved	Noninvolved	Involved	Noninvolved		
Construction						
Surface	6.1	3.3	2.9	1.6	2.9	(1)
Subsurface	6.1	3.3	2.9	1.6	2.9	(1)
Operation and Monitoring						
Operation period						
Surface	3	3.3	1.2	1.6	2.9	(3)
Subsurface - emplacement	3	3.3	1.2	1.6	2.9	(3)
Subsurface - drift development	6.8	1.1	4.8	0.7	2.9	(2)
Monitoring period						
Surface	3	3.3	1.2	1.6	2.9	(3)
Subsurface	3	3.3	1.2	1.6	2.9	(3)
Closure						
Surface	6.1	3.3	2.9	1.6	2.9	(1)
Subsurface	6.1	3.3	2.9	1.6	2.9	(1)

a. FTEs = full-time equivalent worker years.
b. See the discussion about Data Set 4 for source of fatality statistic for normal industrial activities.
c. TRCs = total recordable cases; LWCs = lost workday cases.
d. See text below for source of data in Data Sets 1, 2, and 3.

(Computerized Accident/Incident Reporting and Recordkeeping System) database (DIRS 147938-DOE 1999, all).

Data Set 1, Construction and Construction-Like Activities

This set of statistics from the DOE CAIRS database was applied to construction or construction-like activities. Specifically, it was used for both surface and subsurface workers during the construction phase and the closure phase (closure phase activities were deemed to be construction-like activities). The statistics were based on a 6.75-year period (1992 through the third quarter of 1998).

For involved workers the impact statistic numbers were derived from the totals for all of the DOE construction activities over the period. For noninvolved workers, the values were derived from the combined government and services contractor noninvolved groups for the same period. The noninvolved worker statistic, then, is representative of impacts for oversight personnel who would not be involved in the actual operation of equipment or resources. The basic statistics derived from the CAIRS database for each of the groups include:

- Involved worker total recordable cases: 764 recordable cases for approximately 12,400 full-time equivalent work years

- Involved worker lost workday cases: 367 lost workday cases for approximately 12,400 full-time equivalent work years

- Noninvolved worker total recordable cases: 1,333 recordable cases for approximately 40,600 full-time equivalent work years

- Noninvolved worker lost workday cases: 657 lost workday cases for approximately 40,600 full-time equivalent work years

Data Set 2, Excavation Activities

This set of statistics was derived from experience at the Yucca Mountain Project over a 30-month period (fourth quarter of 1994 though the first quarter of 1997). DOE selected this period because it coincided with the exploratory tunnel boring machine operations at Yucca Mountain, reflecting a high level of worker activity during ongoing excavation activities. This statistic was applied for the Yucca Mountain Project subsurface development period, which principally involves drift development activities. The Yucca Mountain Project experience from which the statistic is derived is presented in Table F-5. DIRS 104543-Stewart (1998, all) contains the Yucca Mountain statistics, which were derived from the CAIRS database (DIRS 147938-DOE 1999, all).

Table F-5. Yucca Mountain Project worker industrial safety loss experience.[a]

Factor	Value[b]	Basis
TRCs[c] per 100 FTEs[d]		
Involved worker	6.8	56 TRCs for 825 construction FTEs
Noninvolved worker	1.1	23 TRCs for 2,015 nonconstruction FTEs
LWCs[e] per 100 FTEs		
Involved worker	4.8	40 LWCs for 825 construction FTEs
Noninvolved worker	0.7	14 LWCs for 2,015 nonconstruction FTEs
Fatality rate occurrence per 100,000 FTEs		
Involved worker	0.0	No fatalities for 825 construction FTEs
Noninvolved worker	0.0	No fatalities for 2,015 nonconstruction FTEs

a. Fourth quarter 1994 through first quarter 1997.
b. Source: Adapted from the CAIRS database (DIRS 147938-DOE 1999, all) by DIRS 104543-Stewart (1998, all) for the fourth quarter of 1994 through the first quarter of 1997.
c. TRCs = total recordable cases.
d. FTEs = full-time equivalent worker years.
e. LWCs = lost workday cases.

Data Set 3, Activities Involving Work in a Radiological Environment

This set of statistics is from the DOE CAIRS database (DIRS 147938-DOE 1999, all). In arriving at the statistics listed in Table F-4, information from the Savannah River Site, the Hanford Site, and the Idaho National Engineering and Environmental Laboratory was averaged individually for the 6.5 years from 1992 through the second quarter of 1998. The averages were then combined to produce an overall average. The reason these three sites were selected as the basis for this set of statistics is that the DOE Savannah River, Hanford, and Idaho National Engineering and Environmental Laboratory sites currently conduct most of the operations in the DOE complex involving handling, sorting, storing, and inspecting spent nuclear fuel and high-level radioactive waste materials, as well as similar activities for low-level radioactive waste materials. The Yucca Mountain Repository phases for which this set of statistics was applied included the receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste in the surface facilities; subsurface emplacement activities; and surface and subsurface monitoring activities, including decontamination of the surface facilities. These activities involve handling, storing, and inspecting spent nuclear fuel and high-level radioactive waste. The worker activities at the Yucca Mountain site are expected to be similar to those cited above for the other sites in the DOE complex.

The basic statistics for the involved and noninvolved workers include:

- Involved worker total recordable cases: 1,246 for about 41,600 full-time equivalent work years
- Involved worker lost workday cases: 538 for about 41,600 full-time equivalent work years
- Noninvolved worker total recordable cases: 1,333 for about 40,600 full-time equivalent work years
- Noninvolved worker lost workday cases: 657 for about 40,600 full-time equivalent work years

Data Set 4, Statistics for Worker Fatalities from Industrial Hazards

There have been no reported fatalities as a result of workplace activities for the Yucca Mountain project. Similarly, there are no fatalities listed in the Mine Safety and Health Administration database for stone mining workers (DIRS 147939-MSHA n.d., all). Because fatalities in industrial operations sometimes occur, the more extensive overall DOE database was used to estimate a fatality rate for the activities at the Yucca Mountain site. Statistics for the DOE facility complex for the 10 years between 1988 and 1997 were used (DIRS 147938-DOE 1999, all). These fatality statistics are for both government and contractor personnel working in the DOE complex who were involved in the operation of equipment and resources (involved workers). The activities in the DOE complex covered by this statistic were governed by safety and administrative controls (under the DOE Order System) that are similar to the safety and administrative controls that would be applied for Yucca Mountain Repository work. These fatality statistics were also applied to the noninvolved worker population because they are the most inclusive statistics in the CAIRS database. However, the statistics probably are conservatively high for the noninvolved worker group.

F.2.2.3 Estimates of Radiological Exposures

DOE considered the following potential sources of radiation exposure for assessing radiological health impacts to workers:

- Inhalation of gaseous radon-222 and its decay products. Subsurface workers could inhale the radon-222 present in the air in the repository drifts. Workers on the surface could inhale radon-222 released to the environment in the exhaust air from the subsurface ventilation system.

- External exposure of surface workers to radioactive gaseous fission products that could be released during handling and packaging of spent nuclear fuel with failed cladding for emplacement in the repository. Such impacts would be of most concern for the uncanistered packaging scenario.

- Direct external exposure of workers in the repository drifts as a result of naturally occurring radionuclides in the walls of the drifts (primarily potassium-40 and radionuclides of the naturally occurring uranium and thorium decay series).

- External exposure of workers to direct radiation emanating from the waste packages containing spent nuclear fuel and high-level radioactive waste either during handling and packaging (surface facility workers) or after it is placed within the waste package (largely subsurface workers).

Section F.1.1.6 describes the approach taken to estimate exposures to workers as a result of inhalation of gaseous radon-222 released from the drift walls to the subsurface atmosphere. For radon exposures to subsurface workers, the analysis assumed a subsurface occupancy factor of 1.0 for involved workers, an occupancy factor of 0.6 for noninvolved workers for construction and drift development activities, and an occupancy factor of 0.4 for noninvolved workers for emplacement, monitoring, and closure (DIRS 104533-Rasmussen 1998, all; DIRS 104536-Rasmussen 1999, all; DIRS 104528-Jessen 1999, all).

As discussed in Section F.1.1.6, the average concentration of radon-222 and its progeny in the subsurface atmosphere varies with factors such as location within the repository (main drifts or emplacement drifts), whether or not concrete lining is in place in the main drifts, the subsurface ventilation rate, and the repository volume. Table F-2 lists estimated doses to subsurface workers from inhalation of radon-222 and its progeny.

Appendix G, Section G.2.3.2, describes the approach taken to estimate source terms and associated doses to workers from the potential release of gaseous fission products from spent nuclear fuel with failed cladding.

Subsurface workers would also be exposed to background gamma radiation from naturally occurring radionuclides in the subsurface rock (largely from the thorium and uranium-238 decay series radionuclides and from potassium-40, all in the rock). DOE has based its projection of worker external gamma dose rates on the data obtained during Exploratory Studies Facility operations (Sections F.1.1.6 and G.2.3.1). The collective ambient radiation exposures for subsurface workers were calculated assuming occupancy factors cited in the previous paragraph for subsurface workers for emplacement and monitoring activities (DIRS 104533-Rasmussen 1998, all; DIRS 104536-Rasmussen 1999, all; DIRS 104528-Jessen 1999, all). The average exposure level, as listed in Table F-8, is 50 millirem per year.

Estimates of subsurface worker exposure as a result of radiation emanating from the waste packages are developed in subsurface facility engineering file (DIRS 150941-CRWMS M&O 2000, Appendix G). Specifically, Tables G-1, G-2, and G-3 of this engineering file list estimates of exposures from the waste packages in the various repository regions. Table G-5 of this engineering file lists manpower distributions for involved workers who would be exposed to radiation emanating from the waste packages. Tables G-4 and G-6 of the engineering file list estimates of annual exposures from radiation emanating from the waste packages. Table F-6 below summarizes the estimates of subsurface worker exposures from radiation emanating from the waste packages during the operation and monitoring and closure phases.

Table F-6. Estimated annual subsurface worker exposures to radiation emanating from waste packages.[a]

	Operating mode				
		Lower-temperature			
Operations phase	Higher-temperature	Long-term ventilation	Long-term ventilation (natural ventilation after 50 years)	Derated waste packages	Maximum spacing
Emplacement					
First 24 years (person-rem per year)[b]	6.0	6.0	6.0	8.3	6.0
Latter period of emplacement for aging cases (person-rem per year)[c]	N/A[d]	6.0	N/A	N/A	6.0
Monitoring (person-rem per year)[e]	3.7	3.7	3.7	3.7	3.7
Monitoring for natural ventilation period (person-rem per year)[f]	N/A	N/A	1.07	N/A	N/A
Closure (overall exposure in person-rem)[g]	270	300	300	330	460

a. Numbers are rounded to two significant figures.
b. Sources: Tables G-4 and G-6 of the Subsurface Engineering File (DIRS 150941-CRWMS M&O 2000).
c. For aging cases, it is assumed that 90 full-time equivalent workers are retained for emplacement. Annual exposure levels are assumed to be the same as for the first 24 years.
d. N/A = not applicable.
e. Source: Table G-6 of the Subsurface Engineering File (DIRS 150941-CRWMS M&O 2000).
f. It is assumed that the annual exposure from radiation emanating from the waste packages is reduced by the ratio of full-time equivalent workers for the forced ventilation period to those for the 250-year natural ventilation period. See Tables I-18 and I-18a for long-term ventilation in letter update to the Subsurface Engineering File (DIRS 155515-Williams 2001, all).
g. Values derived from Appendixes G and H of the Subsurface Engineering File (DIRS 150941-CRWMS M&O 2000).

Table F-7 summarizes the exposure values used in this appendix for estimating overall worker exposures. Values are presented for both the uncanistered packaging scenario and for the dual-purpose canister packaging scenario where appropriate. The table also lists the references or sources from which the data were obtained.

Table F-8 contains estimates of overall annual radiation exposure to surface workers during the waste package handling and packaging operations in preparation for emplacement. The values for the design case with blending are derived from the values listed in Table 6-2 of the Surface Engineering File (DIRS 152010-CRWMS M&O 2000). The estimates for design cases with surface aging prior to emplacement and for the derated waste package design cases were derived from the supplemental information provided in the surface facilities EIS letter report (DIRS 155516-Williams 2001, Section 3.1).

Table F-7. Radiological exposure data used to calculate worker radiological health impacts[a] (page 1 of 2).

Phase and worker group	Exposure source[b]	Occupancy factor[c]	Annual dose (millirem, except where noted)	Annual full-time equivalent workers[d]: Derated waste package	UC[e]	DPC[f]	Data source[g]
Construction							
Surface							
Involved	Radon-222 inhalation	1.0	Small relative to subsurface worker exposures				h
Noninvolved	Radon-222 inhalation	1.0	Small relative to subsurface worker exposures				h
Subsurface							
Involved	Drift ambient	1.0	50				g(1)
	Radon-222 inhalation	1.0	200				Table F-2, g(2)
Noninvolved	Drift ambient	0.6	50				g(1), g(5), g(6)
	Radon-222 inhalation	0.6	60				Table F-2, g(5), g(6)
Surface handling and loading operations							
Involved	Receipt, handling and packaging of spent nuclear fuel and high-level radioactive waste	1.0	Table F-8				See Table F-8
Noninvolved	Receipt, handling and packaging of spent nuclear fuel and high-level radioactive waste	1.0	0				g(7)
Surface							
Involved only	Radon-222 inhalation	1.0	Small relative to subsurface workers				i
Subsurface emplacement							
Involved	Waste package	1.0	Table F-6				Table F-6
	Drift ambient	1.0	50				g(1)
	Radon-222	1.0	120				Table F-2
Noninvolved	Waste package	0.04	200				g(2)
	Drift ambient	0.4	50				g(1), g(5), g(6)
	Radon-222 inhalation	0.4	20				Table F-2, g(5), g(6)
Subsurface drift development							
Involved	Drift ambient	1.0	50				g(1)
	Radon-222 inhalation	1.0	200				Table F-2
Noninvolved	Drift ambient	0.6	50				g(1), g(5), g(6)
	Radon-222 inhalation	0.6	60				Table F-2, g(5), g(6)
Monitoring							
Surface decontamination (postemplacement)							
Involved		1.0	25	2,190	2,663	1,993	g(4), g(8)
Noninvolved		1.0	0	605	689	583	
Subsurface							
Involved	Waste package	1.0	Table F-6				Table F-6
	Drift ambient	1.0	50				g(1)
	Radon-222 inhalation	1.0	100				Table F-2, g(5), g(6)
Noninvolved	Waste package	0.04	200				g(2)
	Drift ambient	0.4	50				g(1), g(5), g(6)
	Radon-222 inhalation	0.4	20				Table F-2, g(5), g(6)
Surface monitoring							
Involved only	Radon-222 inhalation	1.0	Small relative to subsurface workers				j

Table F-7. Radiological exposure data used to calculate worker radiological health impacts[a] (page 2 of 2).

Phase and worker group	Exposure source[b]	Occupancy factor[c]	Annual dose (millirem, except where noted)	Annual full-time equivalent workers[d]: Derated waste package	UC[e]	DPC[f]	Data source[g]
Closure							
Surface							
Involved		1.0	Small relative to subsurface worker exposures				k
Noninvolved		1.0	Small relative to subsurface worker exposures				k
Subsurface							
Involved	Waste package	1.0	Table F-6				Table F-6
	Drift ambient	1.0	50				g(1)
	Radon-222 inhalation	1.0	20				Table F-2
Noninvolved	Waste package	0.04	200				g(2)
	Drift ambient	0.4	50				g(1), g(5), g(6)
	Radon-22 inhalation	0.4	20				Table F-2, g(5), g(6)

a. Numbers are rounded to two significant figures.
b. Exposure sources include radiation from spent nuclear fuel and high-level radioactive waste packages to surface and subsurface workers, the ambient exposure to subsurface workers from naturally occurring radiation in the drift walls, and internal exposures from inhalation of radon-222 and its decay products in the drift atmosphere by subsurface workers.
c. Fraction of 8-hour workday that workers are exposed.
d. Number of annual full-time equivalent workers for surface facility activities when the number of workers in each exposure category would vary with packaging scenario.
e. UC = uncanistered packaging scenario.
f. DPC = dual-purpose canister packaging scenario.
g. Sources:
   (1) Section F.1.1.6.
   (2) DIRS 104533-Rasmussen (1998, all).
   (3) DIRS 150941-CRWMS M&O (2000 Subsurface Facility Engineering File, Table G-6).
   (4) DIRS 152010-CRWMS M&O (2000 Surface Engineering File, Table 6-4).
   (5) DIRS 104536-Rasmussen (1999, all).
   (6) DIRS 104528-Jessen (1999, all).
   (7) DIRS 152010-CRWMS M&O (2000 Surface Engineering File, Table 6-2).
   (8) DIRS 155516-Williams (2001, Section 3.1).
h. Comparison of information in Chapter 4, Table 4-2 (surface workers) and Table F-11 (subsurface workers).
i. Comparison of information in Chapter 4, Table 4-5 (surface workers) and Tables F-20 and F-21 (subsurface workers).
j. Comparison of information in Chapter 4, Table 4-7 (surface workers) and Table F-30 (subsurface workers).
k. Comparison of information in Chapter 4, Table 4-5 (surface workers) and Table F-37 (subsurface workers).

Table F-8. Estimates of annual exposures (person-rem per year) for surface facility workers during handling and packaging of waste material for emplacement.[a]

Period	Packaging scenario	Blending	Aging via surface storage	Derated waste packages
First 24 years	Uncanistered	230[b]	240[c]	240[c]
	Dual-purpose canister	120[b]	NA[d]	NA
Latter period for aging cases	NA	NA	160[e]	NA

a. Numbers are rounded to two significant figures.
b. DIRS 152010-CRWMS M&O (2000, Table 6-2).
c. DIRS 155516-Williams (2001, Section 3.1); values adjusted upward by a ratio of 119/117 for the uncanistered case.
d. NA = not applicable to the operation listed.
e. For surface storage cases (aging), it is assumed that the annual average cumulative exposure to surface facility workers is two-thirds that for the first 24 years based on handling of about 2,000 MTHM per year rather than 3,000 MTHM per year.

F.2.3 COMPILATION OF DETAILED RESULTS FOR OCCUPATIONAL HEALTH AND SAFETY IMPACTS

F.2.3.1 Occupational Health and Safety Impacts During the Construction Phase

F.2.3.1.1 *Industrial Hazards to Workers*

Tables F-9 and F-10 list health and safety impacts from industrial hazards to surface and subsurface workers, respectively, for construction activities.

Table F-9. Industrial hazard health and safety impacts to surface facility workers during construction phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	180	160	180 - 210	160
Lost workday cases	84	74	84 - 99	74
Fatalities	0.084	0.074	0.084 - 0.099	0.074
Noninvolved				
Total recordable cases of injury and illness	36	32	36 - 43	32
Lost workday cases	18	16	18 - 21	16
Fatalities	0.032	0.028	0.032 - 0.038	0.028
All workers (totals)[e]				
Total recordable cases of injury and illness	220	190	220 - 250	190
Lost workday cases	100	90	100 - 120	90
Fatalities	0.12	0.10	0.12 - 0.14	0.10

a. Source: Impact rates from Table F-4; includes all construction activities.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-10. Industrial hazard health and safety impacts to subsurface facility workers during construction phase.[a,b]

Worker group	All operating modes
Involved	
Total recordable cases of injury and illness	170
Lost workday cases	79
Fatalities	0.079
Noninvolved	
Total recordable cases of injury and illness	18
Lost workday cases	9
Fatalities	0.016
All workers (totals)[c]	
Total recordable cases of injury and illness	190
Lost workday cases	88
Fatalities	0.095

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. Totals might differ from sums of values due to rounding.

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F.2.3.1.2 *Radiological Health Impacts to Workers*

Table F-11 lists subsurface worker health impacts from inhalation of radon-222 in the subsurface atmosphere and from ambient radiation exposure from radionuclides in the rock of the drift walls. The radiological health impacts to surface workers from inhalation of radon-222 would be small in comparison to those for subsurface workers; therefore, they were not tabulated in this appendix (see Table F-7, Footnotes h to k for sources of comparison).

Table F-11. Radiological health impacts to subsurface facility workers from radon exposure and ambient radiation during construction phase.[a,b]

Worker group	Radon	Ambient radiation	Total[c]
Involved worker			
Dose to maximally exposed worker (millirem)	1,000	250	1,300
Probability of latent cancer fatality	0.0004	0.0001	0.00052
Collective dose (person-rem)	550	140	680
Number of latent cancer fatalities	0.22	0.056	0.27
Noninvolved worker			
Dose to maximally exposed worker (millirem)	180	150	330
Probability of latent cancer fatality	0.000072	0.00006	0.00013
Collective dose (person-rem)	20	17	37
Number of latent cancer fatalities	0.008	0.0068	0.015
All workers (totals)[c]			
Dose to maximally exposed worker (millirem)	1,180	400	1,630
Probability of latent cancer fatality	0.000472	0.00016	0.00065
Collective dose (person-rem)	570	160	720
Number of latent cancer fatalities	0.23	0.064	0.29

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. Totals might differ from sums of values due to rounding.

F.2.3.1.3 *Summary of Impacts for Construction Phase*

Table F-12 summarizes the estimated health and safety impacts from industrial hazards. The radiological health impacts were summarized in Table F-11.

Table F-12. Summary of estimated impacts to workers from industrial hazards during construction phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	340	320	340 - 370	320
Lost workday cases	160	150	160 - 180	150
Fatalities	0.16	0.15	0.16 - 0.18	0.15
Noninvolved				
Total recordable cases of injury and illness	55	50	55 - 61	50
Lost workday cases	27	24	27 - 30	24
Fatalities	0.048	0.044	0.048 - 0.054	0.044
All workers (total)[e]				
Total recordable cases of injury and illness	400	370	400 - 430	370
Lost workday cases	190	170	190 - 210	170
Fatalities	0.21	0.19	0.21 - 0.23	0.19

a. Values are sums of values in Tables F-9 and F-10.
b. Includes all construction activities.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

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F.2.3.2 Occupational Health and Safety Impacts During the Operations Period

F.2.3.2.1 *Industrial Safety Hazards to Workers*

Table F-13 lists the estimated impacts from industrial hazards for the surface facility workers during waste receipt and packaging, surface storage of waste, retrieval of the waste from surface storage, and preparation of the stored waste for emplacement. Table F-14 lists the estimated impacts from industrial hazards to subsurface workers involved in drift development activities, and Table F-15 lists estimated impacts from industrial hazards to subsurface workers involved in emplacement activities.

Table F-13. Industrial hazard health and safety impacts to surface facility workers involved in waste receipt and packaging activities.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	690	440	690 - 1,100	440
Lost workday cases	280	180	280 - 430	180
Fatalities	0.67	0.43	0.67 - 1.1	0.43
Noninvolved				
Total recordable cases of injury and illness	270	310	270 - 420	310
Lost workday cases	130	150	130 - 200	150
Fatalities	0.24	0.27	0.24 - 0.37	0.27
All workers (total)[e]				
Total recordable cases of injury and illness	960	750	960 - 1500	750
Lost workday cases	410	330	410 - 630	330
Fatalities	0.91	0.7	0.91 - 1.5	0.7

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-14. Industrial hazard health and safety impacts to subsurface workers involved in drift development activities.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	420	420	450 - 510	450
Lost workday cases	300	300	320 - 360	320
Fatalities	0.18	0.18	0.19 - 0.22	0.19
Noninvolved				
Total recordable cases of injury and illness	22	22	24	24
Lost workday cases	14	14	15	15
Fatalities	0.058	0.058	0.064	0.064
All workers (total)[e]				
Total recordable cases of injury and illness	440	440	470 - 530	470
Lost workday cases	310	310	340 - 380	340
Fatalities	0.24	0.24	0.25 - 0.28	0.25

a. Source: Calculated using impact rates from Tables F-4 and F-5.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-15. Industrial health hazard and safety impacts to subsurface facility workers involved in emplacement activities.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	53	53	53 - 110	53
Lost workday cases	21	21	21 - 44	21
Fatalities	0.052	0.052	0.052 - 0.11	0.052
Noninvolved				
Total recordable cases of injury and illness	13	13	13 - 26	13
Lost workday cases	6.1	6.1	6.1 - 13	6.1
Fatalities	0.011	0.011	0.011 - 0.023	0.011
All workers (total)[e]				
Total recordable cases of injury and illness	66	66	66 - 140	66
Lost workday cases	27	27	27 - 57	27
Fatalities	0.063	0.063	0.063 - 0.13	0.063

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.2.3.2.2 *Radiological Health Impacts to Workers*

Radiological health impacts to surface and subsurface workers are listed in Tables F-16 through F-21.

- Table F-16 summarizes the radiological health impacts to surface facility workers involved in handling and packaging of incoming waste materials, surface storage of materials, and recovery and repackaging of the stored materials.
- Table F-17 lists radiological health impacts from radiation emanating from waste packages to subsurface workers involved in emplacement activities.
- Table F-18 lists radiological health impacts from ambient radiation emanating from drift walls to subsurface facility workers involved in emplacement activities.
- Table F-19 lists radiological health impacts from ambient radiation emanating from the drift walls to subsurface workers involved in drift development activities.
- Table F-20 lists radiological health impacts from inhalation of radon-222 and its decay products to subsurface workers involved in emplacement activities.
- Table F-21 lists radiological health impacts from inhalation of radon-222 and its decay products to subsurface workers involved in drift development activities.

Table F-16. Estimated exposures and radiological health impacts to surface facility workers during the operations period.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	9,600	9,600	9,600 - 18,000	9,600
Probability of latent cancer fatality	0.0038	0.0038	0.0038 - 0.0072	0.0038
Collective dose (person-rem)	5,500	2,800	5,500 - 9,100	2,800
Number of latent cancer fatalities	2.2	1.1	2.2 - 3.6	1.1
Noninvolved worker				
Dose to maximally exposed worker (millirem)	0	0	0	0
Probability of latent cancer fatality	0	0	0	0
Collective dose (person-rem)	0	0	0	0
Number of latent cancer fatalities	0	0	0	0
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	9,600	9,600	9,600 - 18,000	9,600
Probability of latent cancer fatality	0.0038	0.0038	0.0038 - 0.0072	0.0038
Collective dose (person-rem)	5,500	2,800	5,500 - 9,100	2,800
Number of latent cancer fatalities	2.2	1.1	2.2 - 3.6	1.1

a. Source: Exposure values from Table F-10.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-17. Radiological health impacts from radiation emanating from waste packages to subsurface facility workers involved in emplacement activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)[e]	11,000	11,000	11,000 - 22,000	11,000
Probability of latent cancer fatality	0.0044	0.0044	0.0044 - 0.0088	0.0044
Collective dose (person-rem)	140	140	140 - 290	140
Number of latent cancer fatalities	0.056	0.056	0.056 - 0.12	0.056
Noninvolved worker				
Dose to maximally exposed worker (millirem)	190	190	190 - 400	190
Probability of latent cancer fatality	0.000076	0.000076	0.000076 - 0.00016	0.000076
Collective dose (person-rem)	3.1	3.1	3.1 - 6.4	3.1
Number of latent cancer fatalities	0.0012	0.0012	0.0012 - 0.0026	0.0012
All workers (totals)[f]				
Dose to maximally exposed worker (millirem)	11,190	11,190	11,190 - 22,400	11,190
Probability of latent cancer fatality	0.004476	0.004476	0.004476 - 0.00896	0.004476
Collective dose (person-rem)	140	140	140 - 300	140
Number of latent cancer fatalities	0.056	0.056	0.056 - 0.12	0.056

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Maximally exposed individual, (DIRS 150941-CRWMS M&O 2000, Table G-4).
f. Totals might differ from sums of values due to rounding.

Table F-18. Radiological health impacts from ambient radiation to subsurface facility workers involved in emplacement activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	1,200	1,200	1,200 - 2,500	1,200
Probability of latent cancer fatality	0.00048	0.00048	0.00048 - 0.001	0.00048
Collective dose (person-rem)	89	89	89 - 190	89
Number of latent cancer fatalities	0.036	0.036	0.036 - 0.076	0.036
Noninvolved worker				
Dose to maximally exposed worker (millirem)	480	480	480 - 1,000	480
Probability of latent cancer fatality	0.00019	0.00019	0.00019 - 0.0004	0.00019
Collective dose (person-rem)	7.7	7.7	7.7 - 16	7.7
Number of latent cancer fatalities	0.0031	0.0031	0.0031 - 0.006	0.0031
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	1,680	1,680	1,680 - 3,500	1,680
Probability of latent cancer fatality	0.00067	0.00067	0.00067 - 0.0014	0.00067
Collective dose (person-rem)	97	97	97 - 210	97
Number of latent cancer fatalities	0.039	0.039	0.039 - 0.08	0.039

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-19. Radiological impacts from ambient radiation to subsurface workers involved in development activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	1,100	1,100	1,100	1,100
Probability of latent cancer fatality	0.00044	0.00044	0.0004	0.00044
Collective dose (person-rem)	310	310	330 - 370	330
Number of latent cancer fatalities	0.12	0.12	0.13 - 0.15	0.13
Noninvolved worker				
Dose to maximally exposed worker (millirem)	660	660	660	660
Probability of latent cancer fatality	0.00026	0.00026	0.00026	0.00026
Collective dose (person-rem)	60	60	66	66
Number of latent cancer fatalities	0.024	0.024	0.026	0.026
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	1,760	1,760	1,760	1,760
Probability of latent cancer fatality	0.0007	0.0007	0.00066	0.0007
Collective dose (person-rem)	370	370	400 - 440	400
Number of latent cancer fatalities	0.15	0.15	0.16 - 0.18	0.16

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-20. Radiological health impacts from airborne radon-222 to subsurface facility workers involved in emplacement activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	2,900	2,900	2,900 - 6,000	2,900
Probability of latent cancer fatality	0.0012	0.0012	0.0012 - 0.0024	0.0012
Collective dose (person-rem)	210	210	210 - 440	210
Number of latent cancer fatalities	0.084	0.084	0.084 - 0.18	0.084
Noninvolved worker				
Dose to maximally exposed worker (millirem)	190	190	190 - 400	190
Probability of latent cancer fatality	0.000076	0.000076	0.000076 - 0.00016	0.000076
Collective dose (person-rem)	3.1	3.1	3.1 - 6.4	3.1
Number of latent cancer fatalities	0.0012	0.0012	0.0012 - 0.0026	0.0012
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	3,090	3,090	3,090 - 6,400	3,090
Probability of latent cancer fatality	0.001276	0.001276	0.001276 - 0.00256	0.001276
Collective dose (person-rem)	210	210	210 - 450	210
Number of latent cancer fatalities	0.084	0.084	0.084 - 0.18	0.084

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-21. Radiological health impacts from airborne radon-222 to subsurface facility workers involved in development activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	4,400	4,400	4,400	4,400
Probability of latent cancer fatality	0.0018	0.0018	0.0018	0.0018
Collective dose (person-rem)	1,200	1,200	1,300 - 1,500	1,300
Number of latent cancer fatalities	0.48	0.48	0.52 - 0.60	0.52
Noninvolved worker				
Dose to maximally exposed worker (millirem)	790	790	790	790
Probability of latent cancer fatality	0.00032	0.00032	0.00032	0.00032
Collective dose (person-rem)	72	72	79	79
Number of latent cancer fatalities	0.029	0.029	0.032	0.032
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	5,190	5,190	5,190	5,190
Probability of latent cancer fatality	0.00212	0.00212	0.00212	0.00212
Collective dose (person-rem)	1,300	1,300	1,400 - 1,600	1,400
Number of latent cancer fatalities	0.52	0.52	0.55 - 0.64	0.56

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.2.3.2.3 *Summary of Impacts for the Operations Period*

Tables F-22 and F-23 summarize the estimated safety and health impacts to workers during the operations period from industrial hazards and from radiological hazards, respectively.

Table F-22. Estimated impacts to workers from industrial hazards during the operations period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	1,200	910	1,200 - 1,700	940
Lost workday cases	590	490	620 - 840	510
Fatalities	0.9	0.66	0.91 - 1.4	0.67
Noninvolved				
Total recordable cases of injury and illness	300	340	310 - 470	340
Lost workday cases	150	170	150 - 230	170
Fatalities	0.31	0.34	0.31 - 0.45	0.35
All workers (totals)[e]				
Total recordable cases of injury and illness	1,500	1,300	1,500 - 2,200	1,300
Lost workday cases	740	660	770 - 1,100	680
Fatalities	1.2	1.0	1.2 - 1.9	1.0

a. Source: Sum of impacts listed in Tables F-13, F-14, and F-15.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = disposal canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-23. Summary of estimated dose and radiological health impacts to workers for the repository operations period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	15,000	15,000	15,000 - 30,000	15,000
Probability of latent cancer fatality	0.006	0.006	0.006 - 0.012	0.006
Collective dose (person-rem)	7,500	4,800	7,600 - 12,000	4,900
Number of latent cancer fatalities	3	1.9	3 - 4.8	2
Noninvolved worker				
Dose to maximally exposed worker (millirem)	1,500	1,500	1,500 - 1,800	1,500
Probability of latent cancer fatality	0.0006	0.0006	0.0006 - 0.00072	0.0006
Collective dose (person-rem)	150	150	160 - 170	160
Number of latent cancer fatalities	0.06	0.06	0.064 - 0.068	0.064
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	16,500	16,500	16,500 - 31,800	16,500
Probability of latent cancer fatality	0.0066	0.0066	0.0066 - 0.01272	0.0066
Collective dose (person-rem)	7,700	5,000	7,800 - 12,000	5,100
Number of latent cancer fatalities	3.1	2	3.1 - 4.8	2.0

a. Source: Sum of impacts listed in Tables F-16, F-17, F-18, F-19, F-20, and F-21.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

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F.2.3.3 Occupational Health and Safety Impacts to Workers During the Monitoring and Caretaking Period

F.2.3.3.1 *Health and Safety Impacts to Workers from Workplace Industrial Hazards*

Health and safety impacts from industrial hazards common to the workplace for the monitoring period consist of the following:

- Impacts to surface facility workers for the 3-year surface facility decontamination period (Table F-24)
- Impacts to surface facility workers for monitoring support activities (Table F-25)
- Impacts to subsurface facility workers for monitoring and maintenance activities (Table F-26)

Table F-24. Industrial hazard health and safety impacts to surface facility workers during the decontamination period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	80	59	66 - 80	59
Lost workday cases	32	24	26 - 32	24
Fatalities	0.077	0.057	0.064 - 0.077	0.057
Noninvolved				
Total recordable cases of injury and illness	23	20	20 - 23	20
Lost workday cases	11	9.7	9.7 - 11	9.7
Fatalities	0.02	0.018	0.018 - 0.02	0.018
All workers (total)[e]				
Total recordable cases of injury and illness	100	79	86 - 100	79
Lost workday cases	43	34	36 - 43	34
Fatalities	0.097	0.075	0.082 - 0.97	0.075

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.2.3.3.2 *Radiological Health Impacts to Workers*

F.2.3.3.2.1 Surface Facility Workers. During monitoring, surface facility workers would be involved in two types of activities with the potential for worker exposure. They are (a) a three-year decontamination operation after the completion of emplacement, and (b) support of subsurface monitoring and caretaking activities by surface facility workers for an additional 73 years for the higher-temperature scenarios. For the lower-temperature scenarios, the lengths of the support period for monitoring and caretaking activities by surface facility workers would be 122 years for the maximum spacing scenarios and 297 years for the long-term ventilation scenarios.

Surface facility workers providing support for the subsurface monitoring and caretaking activities would receive very little exposure in comparison to their counterparts involved in the subsurface monitoring and caretaking activities (see Table F-7, footnote j).

Radiological health impacts for the workers involved in surface facility decontamination activities are listed in Table F-27.

Table F-25. Industrial hazard health and safety impacts to surface facility workers during the monitoring and caretaking period.[a,b,c,d]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[e]	DPC[f]	UC range	DPC
Involved				
Total recordable cases of injury and illness	83	83	110 - 330	330
Lost workday cases	33	33	44 - 130	130
Fatalities	0.08	0.08	0.11 - 0.32	0.32
Noninvolved				
Total recordable cases of injury and illness	0	0	0	0
Lost workday cases	0	0	0	0
Fatalities	0	0	0	0
All workers (total)[g]				
Total recordable cases of injury and illness	83	83	110 - 330	330
Lost workday cases	33	33	44 - 130	130
Fatalities	0.08	0.08	0.11 - 0.32	0.32

a. Source: Calculated using impact rates from Table F-4.
b. All workers are considered to be involved workers.
c. Includes full-time equivalent worker years for solar power generating facility monitoring and maintenance.
d. Numbers are rounded to two significant figures.
e. UC = uncanistered packaging scenario.
f. DPC = dual-purpose canister packaging scenario.
g. Totals might differ from sums of values due to rounding.

Table F-26. Industrial hazard health and safety impacts for subsurface workers during the monitoring period.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	160	160	200 - 620	620
Lost workday cases	63	63	82 - 250	250
Fatalities	0.15	0.15	0.20 - 0.60	0.60
Noninvolved				
Total recordable cases of injury and illness	33	33	42 - 130	130
Lost workday cases	16	16	21 - 62	62
Fatalities	0.029	0.029	0.037 - 0.11	0.11
All workers (total)[e]				
Total recordable cases of injury and illness	190	190	240 - 750	750
Lost workday cases	79	79	100 - 310	310
Fatalities	0.18	0.18	0.24 - 0.71	0.71

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

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Table F-27. Radiological health impacts to surface facility workers during facility decontamination.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Dose to maximally exposed worker (millirem)	75	75	75	75
Probability of latent cancer fatality	0.000030	0.000030	0.000030	0.000030
Collective dose (person-rem)	67	49	55 - 67	49
Number of latent cancer fatalities	0.027	0.020	0.022 - 0.027	0.020

a. Source: Dose rates from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.

F.2.3.3.2.2 Subsurface Facility Workers. There are three exposure components which contribute to radiological health impacts to subsurface facility workers during the monitoring and caretaking phase. They are exposure from radiation emanating from the waste packages, exposure from the ambient radiation emanating from the drift walls, and exposure from inhalation of radon-222 and its progeny which are present in the subsurface atmosphere. Exposures to the subsurface workers during the monitoring and caretaking phase for each of these three components are listed in Tables F-28, F-29, and F-30, respectively. Exposures to the maximally exposed individual worker were based on a maximum work period of 50 years for an individual worker when the length of the monitoring periods is longer than 50 years.

Table F-28. Radiological health impacts to subsurface facility workers from waste package exposure during the monitoring and caretaking period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	10,000	10,000	10,000	10,000
Probability of latent cancer fatality	0.0040	0.0040	0.0040	0.0040
Collective dose (person-rem)	280	280	370 - 1,100	1,100
Number of latent cancer fatalities	0.11	0.11	0.15 - 0.44	0.44
Noninvolved worker				
Dose to maximally exposed worker (millirem)	400	400	400	400
Probability of latent cancer fatality	0.00016	0.00016	0.00016	0.00016
Collective dose (person-rem)	7.9	7.9	10 - 31	31
Number of latent cancer fatalities	0.0032	0.0032	0.004 - 0.012	0.012
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	10,400	10,400	10,400	10,400
Probability of latent cancer fatality	0.00416	0.00416	0.00416	0.00416
Collective dose (person-rem)	290	290	380 - 1,100	1,100
Number of latent cancer fatalities	0.12	0.12	0.15 - 0.44	0.44

a. Source: Exposure data from Table F-6.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-29. Radiological health impacts to subsurface facility workers from ambient radiation during the monitoring and caretaking period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	2,500	2,500	2,500	2,500
Probability of latent cancer fatality	0.001	0.001	0.001	0.001
Collective dose (person-rem)	260	260	340 - 1,000	1,000
Number of latent cancer fatalities	0.10	0.10	0.14 - 0.40	0.40
Noninvolved worker				
Dose to maximally exposed worker (millirem)	1,000	1,000	1,000	1,000
Probability of latent cancer fatality	0.0004	0.0004	0.0004	0.0004
Collective dose (person-rem)	20	20	26 - 78	78
Number of latent cancer fatalities	0.008	0.008	0.01 - 0.031	0.031
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	3,500	3,500	3,500	3,500
Probability of latent cancer fatality	0.0014	0.0014	0.0014	0.0014
Collective dose (person-rem)	280	280	370 - 1,100	1,100
Number of latent cancer fatalities	0.11	0.11	0.15 - 0.44	0.44

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-30. Radiological health impacts to subsurface facility workers from inhalation of radon-222 during the monitoring and caretaking period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	5,000	5,000	5,000	5,000
Probability of latent cancer fatality	0.002	0.002	0.002	0.002
Collective dose (person-rem)	520	520	680 - 2,100	2,100
Number of latent cancer fatalities	0.21	0.21	0.27 - 0.84	0.84
Noninvolved worker				
Dose to maximally exposed worker (millirem)	400	400	400	400
Probability of latent cancer fatality	0.00016	0.00016	0.00016	0.00016
Collective dose (person-rem)	7.9	7.9	10 - 31	31
Number of latent cancer fatalities	0.0032	0.0032	0.004 - 0.012	0.012
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	5,400	5,400	5,400	5,400
Probability of latent cancer fatality	0.00216	0.00216	0.00216	0.00216
Collective dose (person-rem)	530	530	690 - 2,100	2,100
Number of latent cancer fatalities	0.21	0.21	0.28 - 0.84	0.84

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.2.3.3.3 *Summary of Health Impacts for the Monitoring Phase*

Tables F-31 and F-32 summarize health and safety impacts from industrial hazards and from radiological hazards, respectively.

Table F-31. Estimated impacts to workers from industrial hazards during the monitoring and caretaking period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	320	300	400 - 1,000	1,000
Lost workday cases	130	120	160 - 410	410
Fatalities	0.31	0.29	0.38 - 1.0	0.98
Noninvolved				
Total recordable cases of injury and illness	55	53	65 - 150	150
Lost workday cases	27	25	32 - 73	72
Fatalities	0.049	0.046	0.057 - 0.13	0.13
All workers (total)[e]				
Total recordable cases of injury and illness	380	350	470 - 1,200	1,200
Lost workday cases	160	150	190 - 480	480
Fatalities	0.36	0.34	0.44 - 1.1	1.1

a. Values presented in this table are the sum of the estimates from Tables F-24, F-25, and F-26.
b. Values are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-32. Radiological health impacts to workers for the monitoring and caretaking period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	18,000	18,000	18,000	18,000
Probability of latent cancer fatality	0.0072	0.0072	0.0072	0.0072
Collective dose (person-rem)	1,100	1,100	1,500 - 4,300	4,300
Number of latent cancer fatalities	0.44	0.44	0.6 - 1.7	1.7
Noninvolved worker				
Dose to maximally exposed worker (millirem)	1,800	1,800	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072	0.00072	0.00072
Collective dose (person-rem)	36	36	46 - 140	140
Number of latent cancer fatalities	0.014	0.014	0.018 - 0.056	0.056
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	19,800	19,800	19,800	19,800
Probability of latent cancer fatality	0.00792	0.00792	0.00792	0.00792
Collective dose (person-rem)	1,100	1,100	1,500 - 4,400	4,400
Number of latent cancer fatalities	0.44	0.44	0.6 - 1.8	1.8

a. Values in this table are the sum of the values in Tables F-27, F-28, F-29, and F-30.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.2.3.4 Occupational Health and Safety Impacts During the Closure Phase

F.2.3.4.1 *Health and Safety Impacts to Workers from Workplace Industrial Hazards*

Health and safety impacts to workers from industrial hazards common to the workplace for the closure phase are listed in Table F-33 for surface facility workers and Table F-34 for subsurface facility workers.

Table F-33. Industrial hazard health and safety impacts to surface facility workers during the closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	180	160	180	160
Lost workday cases	85	75	85	75
Fatalities	0.085	0.075	0.085	0.075
Noninvolved				
Total recordable cases of injury and illness	37	32	37	32
Lost workday cases	18	16	18	16
Fatalities	0.032	0.028	0.032	0.028
All workers (total)[e]				
Total recordable cases of injury and illness	220	190	220	190
Lost workday cases	100	91	100	91
Fatalities	0.12	0.10	0.12	0.10

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-34. Industrial hazard health and safety impacts to subsurface facility workers during the closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	150	150	160 - 250	160
Lost workday cases	69	69	76 - 120	76
Fatalities	0.069	0.069	0.076 - 0.12	0.076
Noninvolved				
Total recordable cases of injury and illness	15	15	16 - 25	16
Lost workday cases	7.2	7.2	7.9 - 12	7.9
Fatalities	0.013	0.013	0.014 - 0.022	0.014
All workers (total)[e]				
Total recordable cases of injury and illness	170	170	180 - 280	180
Lost workday cases	76	76	84 - 130	84
Fatalities	0.082	0.082	0.09 - 0.14	0.09

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.2.3.4.2 *Radiological Health Impacts to Workers*

Radiological health impact to workers from closure activities are the sum of the following components:

- Radiological health impacts to subsurface workers from radiation emanating from the waste packages during the closure phase (Table F-35)
- Radiological impacts to subsurface workers from the ambient radiation field in the drifts during the closure phase (Table F-36)
- Radiological impacts to subsurface workers from inhalation of radon-222 in the drift atmosphere during the closure phase (Table F-37)

Table F-35. Radiological health impacts to subsurface workers from radiation emanating from waste packages during closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	6,000	6,000	7,100 - 12,000	7,100
Probability of latent cancer fatality	0.0024	0.0024	0.0028 - 0.0048	0.0028
Collective dose (person-rem)	270	270	300 - 460	300
Number of latent cancer fatalities	0.11	0.11	0.12 - 0.18	0.12
Noninvolved worker				
Dose to maximally exposed worker (millirem)	80	80	88 - 140	88
Probability of latent cancer fatality	0.000032	0.000032	0.000035 - 0.000056	0.000035
Collective dose (person-rem)	3.6	3.6	4 - 6.1	4
Number of latent cancer fatalities	0.0014	0.0014	0.0016 - 0.0024	0.0016
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	6,080	6,080	7,188 - 12,140	7,188
Probability of latent cancer fatality	0.002432	0.002432	0.002835 - 0.004856	0.002835
Collective dose (person-rem)	270	270	300 - 470	300
Number of latent cancer fatalities	0.11	0.11	0.12 - 0.19	0.12

a. Source: Exposure data from Table F-6.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Because the surface facilities would be largely decontaminated at the beginning of the monitoring period (the exception would be a small facility retained to handle an operations emergency), radiological health impacts to surface facility workers during closure would be small in comparison to those to the subsurface facility workers and so are not included here.

F.2.3.4.3 *Summary of Impacts for Closure Phase*

Tables F-38 and F-39 summarize the estimated health and safety impacts from industrial hazards and from radiological hazards, respectively.

F.2.3.5 Summary of Occupational Health and Safety Impacts for All Repository Phases

The occupational health and safety impacts for all of the repository phases have been summarized in Tables F-40 (impacts from industrial safety hazards) and F-41 (impacts from radiological health hazards).

Table F-36. Radiological health impacts to subsurface workers from ambient radiation during closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	500	500	550 - 850	550
Probability of latent cancer fatality	0.0002	0.0002	0.00022 - 0.00034	0.00022
Collective dose (person-rem)	120	120	130 - 200	130
Number of latent cancer fatalities	0.048	0.048	0.052 - 0.08	0.052
Noninvolved worker				
Dose to maximally exposed worker (millirem)	200	200	220 - 340	220
Probability of latent cancer fatality	0.00008	0.00008	0.000088 - 0.00014	0.000088
Collective dose (person-rem)	9	9	9.9 - 15	9.9
Number of latent cancer fatalities	0.0036	0.0036	0.004 - 0.006	0.004
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	700	700	770 - 1,190	770
Probability of latent cancer fatality	0.00028	0.00028	0.000308 - 0.00048	0.000308
Collective dose (person-rem)	130	130	140 - 220	140
Number of latent cancer fatalities	0.052	0.052	0.056 - 0.088	0.056

a. Source: Exposure values from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-37. Radiological health impacts to subsurface workers from inhalation of radon-222 during closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	200	200	220 - 340	220
Probability of latent cancer fatality	0.00008	0.00008	0.000088 - 0.00014	0.000088
Collective dose (person-rem)	48	48	52 - 81	52
Number of latent cancer fatalities	0.019	0.019	0.021 - 0.032	0.021
Noninvolved worker				
Dose to maximally exposed worker (millirem)	80	80	88 - 140	88
Probability of latent cancer fatality	0.000032	0.000032	0.000035 - 0.000056	0.000035
Collective dose (person-rem)	3.6	3.6	4 - 6.1	4
Number of latent cancer fatalities	0.0014	0.0014	0.0016 - 0.0024	0.0016
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	280	280	308 - 480	308
Probability of latent cancer fatality	0.000112	0.000112	0.000123- 0.000196	0.000123
Collective dose (person-rem)	52	52	56 - 87	56
Number of latent cancer fatalities	0.021	0.021	0.022 - 0.035	0.022

a. Source: Exposure values from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-38. Summary of estimates of impacts to workers from industrial hazards for the closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved				
Total recordable cases of injury and illness	320	300	340 - 420	320
Lost workday cases	150	140	160 - 200	150
Fatalities	0.15	0.14	0.16 - 0.2	0.15
Noninvolved				
Total recordable cases of injury and illness	51	47	53 - 62	49
Lost workday cases	25	23	26 - 30	24
Fatalities	0.045	0.041	0.047 - 0.054	0.043
All workers (total)[e]				
Total recordable cases of injury and illness	370	350	390 - 480	370
Lost workday cases	180	160	190 - 230	170
Fatalities	0.20	0.18	0.21 - 0.25	0.19

a. Data in this table are the sum of the impacts in Tables F-33 and F-34.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-39. Summary of radiological health impacts to subsurface workers for the closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC range	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	6,700	6,700	7,900 - 13,000	7,900
Probability of latent cancer fatality	0.0027	0.0027	0.0032 - 0.0052	0.0032
Collective dose (person-rem)	430	430	480 - 740	480
Number of latent cancer fatalities	0.17	0.17	0.19 - 0.3	0.19
Noninvolved worker				
Dose to maximally exposed worker (millirem)	360	360	400 - 610	400
Probability of latent cancer fatality	0.00014	0.00014	0.00016 - 0.00024	0.00016
Collective dose (person-rem)	16	16	18 - 28	18
Number of latent cancer fatalities	0.0064	0.0064	0.0072 - 0.011	0.0072
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	7,060	7,060	8,300 - 13,610	8,300
Probability of latent cancer fatality	0.00284	0.00284	0.00336 - 0.00544	0.00336
Collective dose (person-rem)	450	450	500 - 770	500
Number of latent cancer fatalities	0.18	0.18	0.2 - 0.31	0.2

a. Data in this table are the sum of the impacts presented in Tables F-35, F-36, and F-37, except for impacts to maximally exposed individuals.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-package canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-40. Summary of impacts to workers from industrial hazards for all phases.[a,b]

Worker group	Operating mode: Higher-temperature UC[c]	Higher-temperature DPC[d]	Lower-temperature UC range	Lower-temperature DPC
Involved				
Total recordable cases of injury and illness	2,200	1,800	2,500 - 3,300	2,600
Lost workday cases	1,000	910	1,200 - 1,500	1,200
Fatalities	1.5	1.2	1.8 - 2.6	2
Noninvolved				
Total recordable cases of injury and illness	470	490	500 - 720	590
Lost workday cases	230	240	250 - 350	290
Fatalities	0.45	0.47	0.48 - 0.68	0.56
All workers (total)[e]				
Total recordable cases of injury and illness	2,700	2,300	3,000 - 4,000	3,200
Lost workday cases	1,200	1,200	1,500 - 1,900	1,500
Fatalities	2.0	1.7	2.3 - 3.3	2.6

a. Estimated impacts in this table are the sums of impacts listed in Tables F-12, F-22, F-31, and F-38.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-41. Summary of radiological health impacts to workers for all phases.[a,b]

Worker group	Operating mode: Higher-temperature UC[c]	Higher-temperature DPC[d]	Lower-temperature UC range	Lower-temperature DPC
Involved worker				
Dose to maximally exposed worker (millirem)	18,000	18,000	18,000 - 30,000	18,000
Probability of latent cancer fatality	0.0072	0.0072	0.0072 - 0.012	0.0072
Collective dose (person-rem)	9,800	7,000	11,000 - 17,000	10,000
Number of latent cancer fatalities	3.9	2.8	4.4 - 6.8	4
Noninvolved worker				
Dose to maximally exposed worker (millirem)	1,800	1,800	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072	0.00072	0.00072
Collective dose (person-rem)	230	230	280 - 360	350
Number of latent cancer fatalities	0.092	0.092	0.11 - 0.14	0.14
All workers (totals)[e]				
Dose to maximally exposed worker (millirem)	20,000	20,000	20,000 - 30,000	20,000
Probability of latent cancer fatality	0.0079	0.0079	0.0079 - 0.012	0.0079
Collective dose (person-rem)	10,000	7,200	11,000 - 17,000	10,000
Number of latent cancer fatalities	4.0	2.9	4.4 - 6.8	4.0

a. Estimated impacts in this table are the sums of the impacts listed in Tables F-11, F-23, F-32, and F-39.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3 Worker Human Health and Safety Impact Analysis for Inventory Modules 1 and 2

DOE performed the same analyses used for the Proposed Action to estimate the occupational and public health and safety impacts from the emplacement of Inventory Module 1 or 2. Module 1 would involve the emplacement of additional spent nuclear fuel and high-level radioactive waste in the repository; Inventory Module 2 would emplace commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste, which is equivalent to commercial Greater-Than-Class-C waste, in addition to the inventory from Module 1. The volumes of Greater-Than-Class-C and Special-Performance-Assessment-Required waste would be less than that for spent nuclear fuel and high-level radioactive waste (DIRS 104508-CRWMS M&O 1999, Table 3.1). Waste packages containing these materials would be placed between the waste packages containing spent nuclear fuel and high-level radioactive waste (see Chapter 8, Section 8.1.2.1).

With regard to estimating heath and safety impacts for the inventory modules, the characteristics of the spent nuclear fuel and high-level radioactive waste were taken to be the same as those for the Proposed Action, but there would be more material to emplace (see Appendix A, Section A.2). As described in Appendix A, the radiological content of the Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste, which is the additional material in Module 2, is much less than that for spent nuclear fuel and high-level radioactive waste. Therefore, the emplacement of the Module 2 material would not meaningfully increase radiological impacts to workers over those estimated for the Module 1 inventory. Further, the facility design parameters, on which the impact estimates are based, are extrapolations from existing designs and have some uncertainty associated with them [see, for example, DIRS 104508-CRWMS M&O (1999), Section 6.2, first paragraph]. Therefore, separate occupational and public health and safety impact analyses were not performed for Module 2 because the impacts for Inventory Modules 1 and 2 would not differ meaningfully.

The calculation of health and safety impacts to workers assumed that the throughput rate of materials for the facility would remain the same as that assumed for the Proposed Action during repository operations (that is, the 70,000-MTHM case). In addition, for the inventory modules the period of operations would be extended to accommodate the additional materials, and the monitoring period would be reduced such that the Yucca Mountain repository operations and monitoring activities would be the same as those for the Proposed Action.

This section discusses the methodologies and data used to estimate occupational radiological health and safety impacts resulting from construction, operation and monitoring, and closure of the Yucca Mountain Repository for Inventory Modules 1 and 2, and presents the detailed results. Section F.3.1 describes the methods DOE used to estimate impacts. Section F.3.2 contains tabulations of the detailed data used in the impact calculations and references to the data sources. Section F.3.3 contains detailed tabulations of results.

F.3.1 METHODOLOGY FOR CALCULATING HUMAN HEALTH AND SAFETY IMPACTS

DOE used the methodology described in Section F.2.1 to estimate health and safety impacts for the inventory modules. This methodology involved assembling data for the number of full-time equivalent workers for each repository phase. These numbers were used with statistics for the likelihood of an impact (industrial hazards) or the expected dose rate in the worker environment to calculate health and safety impacts. The way in which the input data was combined in the calculation of health and safety impacts is described in more detail in Section F.2.1. Some of the input data for the calculations for the inventory modules are different from those for the Proposed Action, as discussed in the next section.

F.3.2 DATA SOURCES AND TABULATIONS

F.3.2.1 Full-Time Equivalent Worker-Year Estimates for the Repository Phases for Inventory Modules 1 and 2

The full-time equivalent worker-year estimates for the inventory modules are different from those for the Proposed Action. Table F-42 lists the number of full-time equivalent work years for the various repository phases for the inventory modules. Each full-time equivalent work year represents 2,000 work hours, the hours assumed to be worked in a normal work year.

This analysis divides the repository workforce into two groups—involved and noninvolved workers (see Section F.2 for definitions of involved and noninvolved workers). It did not consider workers whose place of employment would be other than at the repository site.

F.3.2.2 Statistics on Health and Safety Impacts from Industrial Hazards in the Workplace

DOE used the same statistics for health and safety impacts from industrial hazards common to the workplace that were used for the Proposed Action (70,000 MTHM) for analyzing the inventory module impacts (see Tables F-4 and F-5).

F.3.2.3 Estimates of Radiological Exposure Rates and Times for Inventory Modules 1 and 2

DOE used the values in Tables F-6 through F-8 (Proposed Action) for exposure rates, occupancy times, and the fraction of the workforce that would be exposed to estimate radiological health impacts for the inventory module cases, except for doses from the waste packages and from radon-222 inhalation for the subsurface emplacement, monitoring, and closure phases.

F.3.3 DETAILED HUMAN HEALTH AND SAFETY IMPACTS TO WORKERS–INVENTORY MODULES 1 AND 2

F.3.3.1 Construction Phase

F.3.3.1.1 *Industrial Hazards to Workers*

This section details health and safety impacts to workers from industrial hazards common to the workplace for the construction phase. Because the activities for construction would be the same for the Inventory Modules as they would for the Proposed Action, the industrial safety impacts would also be the same. Impact values for surface workers are presented in Table F-9, while impacts for subsurface workers are presented in Table F-10. Further, Table F-12 summarizes the impacts listed in Tables F-9 and F-10.

F.3.3.1.2 *Radiological Health Impacts to Workers*

Because the activities for construction would be the same for the Inventory Modules as for the Proposed Action, the radiological impacts are also the same. Table F-11 lists subsurface worker health impacts from inhalation of radon-222 and its decay products in the subsurface atmosphere and from exposure to natural radiation from radionuclides in the drift walls, respectively. The radiological health impacts to surface workers from radon-222 and ambient radiation contribute negligibly to the overall impact from these natural sources. Therefore, separate tables are not presented for surface workers.

Table F-42. Full-time equivalent worker years for various repository periods for Inventory Modules 1 and 2 (page 1 of 2).[a]

				Operating mode			
				Higher-temperature		Lower-temperature	
Phase	Subphase	Period	Worker group	UC[b]	DPC[c]	UC (range)	DPC
Construction	Surface	44 months	Involved	2,800	2,500	2,600 - 2,900	2,500
			Noninvolved	1,100	940	990 - 1,100	940
	Subsurface	5 years	Involved	2,700	2,700	2,700	2,700
			Noninvolved	560	560	560	560
	Solar power facility	6 years	Involved	76	76	76	76
			Noninvolved	26	26	26	26
	Aging facilities	16 years	Involved	N/A[d]	N/A	750	N/A
			Noninvolved	N/A	N/A	290	N/A
	Construction subtotals			7,300	6,800	7,300 - 8,000	6,800
Operations	Surface handling	First 38 years	Involved	37,000	23,000	37,000 - 38,000	23,000
			Noninvolved	13,000	15,000	13,000	15,000
		Last 13 years (aging only)	Involved	N/A	N/A	6,400	N/A
			Noninvolved	N/A	N/A	2,200	N/A
	Subsurface emplacement	First 38 years	Involved	2,800	2,800	2,800 - 4,300	2,800
			Noninvolved	610	610	610 - 930	610
		Last 13 years (aging only)	Involved	N/A	N/A	960	N/A
			Noninvolved	N/A	N/A	210	N/A
	Subsurface development	36 years	Involved	10,000	10,000	10,000 - 11,000	10,000
			Noninvolved	2,400	2,400	2,400	2,400
	Operations subtotals			66,000	54,000	66,000 - 77,000	54,000
Monitoring	Surface facility decontamination	3 years	Involved	2,700	2,000	2,200 - 2,700	2,000
			Noninvolved	690	610	610 - 690	610
	Surface	Variable[e]	Involved	2,100	2,100	3,800 - 10,000	10,000
			Noninvolved	0	0	0	0
	Subsurface	Variable[f]	Involved	4,700	4,700	8,100 - 23,000	23,000
			Noninvolved	870	870	1,600 - 4,200	4,200
	Solar panel maintenance	Variable[g]	Involved	180	180	290 - 610	610
	Solar panel replacement	Every 20 years	Involved	36	36	72 - 140	140
	Monitoring subtotals			11,000	10,000	17,000 - 41,000	40,000

Table F-42. Full-time equivalent worker years for various repository periods for Inventory Modules 1 and 2 (page 2 of 2).[a]

				Operating mode			
				Higher-temperature		Lower-temperature	
Phase	Subphase	Period	Worker group	UC[b]	DPC[c]	UC (range)	DPC
Closure	Surface facilities	6 years	Involved	2,900	2,500	2,900	2,500
			Noninvolved	1,100	950	1,100	950
	Subsurface	Variable[h]	Involved	2,900	2,900	3,600 - 6,900	3,800
			Noninvolved	540	540	680 - 1,400	720
	Solar power facility	6 years	Involved	62	62	62	62
			Noninvolved	24	24	24	24
	Closure subtotals			7,400	6,900	8,300 - 12,000	8,100
Totals				***92,000***	***78,000***	***110,000 - 130,000***	***110,000***

a. Sources: Derived from DIRS 152010-CRWMS M&O (2000, all); DIRS 150941-CRWMS M&O (2000, all); DIRS 155515-Williams (2001, all); DIRS 155516-Williams (2001, all); DIRS 153882-Griffith (2001, all); DIRS 154758-Lane (2000, all); DIRS 153958-Morton (2000, all).

b. UC = uncanistered packaging scenario.

c. DPC = dual-purpose canister packaging scenario.

d. N/A = not applicable.

e. Surface monitoring periods are 73 years for the higher-temperature cases (UC and DPC), 297 years for the lower-temperature DPC case, and ranges from 96 to 271 years for the remaining cases.

f. Subsurface monitoring periods are 76 years for the higher-temperature cases (UC and DPC), 300 years for the lower-temperature DPC case, and ranges from 99 to 274 years for the remaining cases.

g. Solar power maintenance periods are 100 years for the higher-temperature cases (UC and DPC), 324 years for the lower-temperature DPC case, and either 149 or 324 years for the remaining cases.

h. Subsurface closure periods are 10 years for the higher-temperature cases (UC and DPC), 11 years for the lower-temperature DPC case, and either 12 or 17 years for the remaining cases.

F.3.3.2 Operations Period

F.3.3.2.1 *Health and Safety Impacts to Workers from Industrial Hazards*

This section details health and safety impacts to workers from industrial hazards common to the workplace for the operations period. These impacts would consist of three components:

- Health and safety impacts to surface workers for operations (Table F-43)
- Health and safety impacts to subsurface workers for drift development (Table F-44)
- Health and safety impacts to subsurface workers for emplacement (Table F-45)

Table F-43. Industrial hazard health and safety impacts for surface facility workers during the operations period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	1,100	700	1,100 - 1,300	700
Lost workday cases	440	280	440 - 520	280
Fatalities	1.1	0.68	1.1 - 1.3	0.68
Noninvolved workers				
Total recordable cases of injury and illness	430	490	430 - 500	490
Lost workday cases	210	240	210 - 240	240
Fatalities	0.38	0.43	0.38 - 0.44	0.43
All workers[e]				
Total recordable cases of injury and illness	1,500	1,200	1,500 - 1,800	1,200
Lost workday cases	650	520	650 - 760	520
Fatalities	1.5	1.1	1.5 - 1.7	1.1

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3.3.2.2 *Radiological Health Impacts to Workers*

This section details radiological health impacts to workers during the operation and monitoring phase for the inventory modules. These impacts consist of three components:

- Radiological health impacts to surface workers from waste packages during operations (Table F-46)
- Radiological health impacts to subsurface workers involved in drift development activities (Tables F-47 and F-48)
- Radiological health impacts to subsurface workers involved in emplacement activities (Tables F-49 through F-51)

Table F-44. Industrial hazard health and safety impacts to subsurface facility workers involved in drift development activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	700	700	700 - 760	700
Lost workday cases	490	490	490 - 540	490
Fatalities	0.3	0.3	0.3 - 0.33	0.3
Noninvolved workers				
Total recordable cases of injury and illness	27	27	27	27
Lost workday cases	17	17	17	17
Fatalities	0.071	0.071	0.071	0.071
All workers[e]				
Total recordable cases of injury and illness	730	730	730 - 790	730
Lost workday cases	510	510	510 - 560	510
Fatalities	0.37	0.37	0.37 - 0.4	0.37

a. Source: Calculated using impact rates from Table F-5.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-45. Industrial hazard health and safety impacts to subsurface facility workers involved in emplacement activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	84	84	84 - 130	84
Lost workday cases	34	34	34 - 51	34
Fatalities	0.082	0.082	0.082 - 0.12	0.082
Noninvolved workers				
Total recordable cases of injury and illness	20	20	20 - 31	20
Lost workday cases	9.7	9.7	9.7 - 15	9.7
Fatalities	0.018	0.018	0.018 - 0.027	0.018
All workers[e]				
Total recordable cases of injury and illness	100	100	100 - 160	100
Lost workday cases	44	44	44 - 66	44
Fatalities	0.1	0.1	0.1 - 0.15	0.1

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-46. Radiological health impacts from waste packages to surface facility workers during operations period.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	15,000	15,000	15,000 - 20,000	15,000
Probability of latent cancer fatality	0.006	0.006	0.006 - 0.008	0.006
Collective dose (person-rem)	8,800	4,400	8,800 - 11,000	4,400
Number of latent cancer fatalities	3.5	1.8	3.5 - 4.4	1.8
Noninvolved worker				
Dose to maximally exposed worker (millirem)	0	0	0	0
Probability of latent cancer fatality	0	0	0	0
Collective dose (person-rem)	0	0	0	0
Number of latent cancer fatalities	0	0	0	0
All workers[e]				
Collective dose (person-rem)	8,800	4,400	8,800 - 11,000	4,400
Number of latent cancer fatalities	3.5	1.8	3.5 - 4.4	1.8

a. Source: Calculated using exposure rate from Table F-8.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-47. Radiological health impacts from ambient radiation to subsurface facility workers involved in drift development activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	1,800	1,800	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072	0.00072	0.00072
Collective dose (person-rem)	510	510	510 - 560	510
Number of latent cancer fatalities	0.2	0.2	0.2 - 0.22	0.2
Noninvolved worker				
Dose to maximally exposed worker (millirem)	1,100	1,100	1,100	1,100
Probability of latent cancer fatality	0.00044	0.00044	0.00044	0.00044
Collective dose (person-rem)	73	73	73	73
Number of latent cancer fatalities	0.029	0.029	0.029	0.029
All workers[e]				
Collective dose (person-rem)	580	580	580 - 630	580
Number of latent cancer fatalities	0.23	0.23	0.23 - 0.25	0.23

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-48. Radiological health impacts from radon exposure to subsurface facility workers involved in drift development activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	7,200	7,200	7,200	7,200
Probability of latent cancer fatality	0.0029	0.0029	0.0029	0.0029
Collective dose (person-rem)	2,100	2,100	2,100 - 2,200	2,100
Number of latent cancer fatalities	0.84	0.84	0.84 - 0.88	0.84
Noninvolved worker				
Dose to maximally exposed worker (millirem)	1,300	1,300	1,300	1,300
Probability of latent cancer fatality	0.00052	0.00052	0.00052	0.00052
Collective dose (person-rem)	88	88	88	88
Number of latent cancer fatalities	0.035	0.035	0.035	0.035
All workers[e]				
Collective dose (person-rem)	2,200	2,200	2,200 - 2,300	2,200
Number of latent cancer fatalities	0.88	0.88	0.88 - 0.92	0.88

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-49. Radiological health impacts from waste packages to subsurface facility workers involved in emplacement activities.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	18,000	18,000	18,000 - 24,000	18,000
Probability of latent cancer fatality	0.0072	0.0072	0.0072 - 0.0096	0.0072
Collective dose (person-rem)	230	230	230 - 340	230
Number of latent cancer fatalities	0.092	0.092	0.092 - 0.14	0.092
Noninvolved worker				
Dose to maximally exposed worker (millirem)	300	300	300 - 410	300
Probability of latent cancer fatality	0.00012	0.00012	0.00012 - 0.00016	0.00012
Collective dose (person-rem)	4.9	4.9	4.9 - 7.4	4.9
Number of latent cancer fatalities	0.002	0.002	0.002 - 0.003	0.002
All workers[e]				
Collective dose (person-rem)	230	230	230 - 350	230
Number of latent cancer fatalities	0.092	0.092	0.092 - 0.14	0.092

a. Source: Exposure data from Table F-6.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

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Table F-50. Radiological health impacts from ambient radiation to subsurface facility workers involved in emplacement activities.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	1,900	1,900	1,900 - 2,600	1,900
Probability of latent cancer fatality	0.00076	0.00076	0.00076 - 0.001	0.00076
Collective dose (person-rem)	140	140	140 - 210	140
Number of latent cancer fatalities	0.056	0.056	0.056 - 0.084	0.056
Noninvolved worker				
Dose to maximally exposed worker (millirem)	760	760	760 - 1,000	760
Probability of latent cancer fatality	0.0003	0.0003	0.0003 - 0.0004	0.0003
Collective dose (person-rem)	12	12	12 - 19	12
Number of latent cancer fatalities	0.0048	0.0048	0.0048 - 0.0076	0.0048
All workers[e]				
Collective dose (person-rem)	150	150	150 - 230	150
Number of latent cancer fatalities	0.06	0.06	0.06 - 0.092	0.06

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-51. Radiological health impacts from radon exposure to subsurface facility workers involved in emplacement activities.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	4,600	4,600	4,600 - 6,100	4,600
Probability of latent cancer fatality	0.0018	0.0018	0.0018 - 0.0024	0.0018
Collective dose (person-rem)	340	340	340 - 510	340
Number of latent cancer fatalities	0.14	0.14	0.14 - 0.2	0.14
Noninvolved worker				
Dose to maximally exposed worker (millirem)	300	300	300 - 410	300
Probability of latent cancer fatality	0.00012	0.00012	0.00012 - 0.00016	0.00012
Collective dose (person-rem)	4.9	4.9	4.9 - 7.4	4.9
Number of latent cancer fatalities	0.002	0.002	0.002 - 0.003	0.002
All workers[e]				
Collective dose (person-rem)	340	340	340 - 520	340
Number of latent cancer fatalities	0.14	0.14	0.14 - 0.21	0.14

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3.3.2.3 *Summary of Impacts for the Operations Period*

Tables F-52 and F-53 present the occupational and radiological impacts, respectively, to all workers from operations activities. In each table, impacts are presented for the higher-temperature repository operating mode uncanistered and dual-purpose canister packaging scenarios; in addition, the range of impacts for the lower-temperature mode (uncanistered packaging scenario) is presented along with the impacts for the dual-purpose canister scenario that uses long-term ventilation without aging.

Table F-52. Summary of industrial hazard health and safety impacts to facility workers during operations period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	1,900	1,500	1,900 - 2,200	1,500
Lost workday cases	970	810	970 - 1,100	810
Fatalities	1.4	1.1	1.4 - 1.7	1.1
Noninvolved workers				
Total recordable cases of injury and illness	470	530	470 - 560	530
Lost workday cases	230	260	230 - 270	260
Fatalities	0.46	0.52	0.46 - 0.54	0.52
All workers[e]				
Total recordable cases of injury and illness	2,400	2,000	2,400 - 2,800	2,000
Lost workday cases	1,200	1,100	1,200 - 1,400	1,100
Fatalities	1.9	1.6	1.9 - 2.2	1.6

a. Sources: Tables F-43, F-44, and F-45.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-53. Summary of radiological health impacts to workers from all activities during operations period.

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	24,000	24,000	24,000 - 33,000	24,000
Probability of latent cancer fatality	0.0096	0.0096	0.0096 - 0.013	0.0096
Collective dose (person-rem)	12,000	7,700	12,000 - 15,000	7,700
Number of latent cancer fatalities	4.8	3.1	4.8 - 6	3.1
Noninvolved worker				
Dose to maximally exposed worker (millirem)	2,400	2,400	2,400	2,400
Probability of latent cancer fatality	0.00096	0.00096	0.00096	0.00096
Collective dose (person-rem)	180	180	180 - 190	180
Number of latent cancer fatalities	0.072	0.072	0.072 - 0.076	0.072
All workers[e]				
Collective dose (person-rem)	12,000	7,900	12,000 - 15,000	7,900
Number of latent cancer fatalities	4.8	3.2	4.8 - 6	3.2

a. Sources: Tables F-46, F-47, F-48, F-49, and F-50.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3.3.3 Occupational Health and Safety Impacts to Workers During the Monitoring and Caretaking Period

F.3.3.3.1 *Health and Safety Impacts to Workers from Workplace Industrial Hazards*

Health and safety impacts from industrial hazards common to the workplace for the monitoring period consist of the following:

- Impacts to surface facility workers for the 3-year surface facility decontamination period. These values, which are the same as those for the Proposed Action, are listed in Table F-24.
- Impacts to surface facility workers for monitoring support activities (Table F-54)
- Impacts to subsurface facility workers for monitoring and maintenance activities (Table F-55)

Table F-54. Industrial hazard health and safety impacts to surface facility workers during the monitoring period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	68	68	130 - 330	330
Lost workday cases	27	27	50 - 130	130
Fatalities	0.066	0.066	0.12 - 0.32	0.32
Noninvolved workers				
Total recordable cases of injury and illness	0	0	0	0
Lost workday cases	0	0	0	0
Fatalities	0	0	0	0
All workers[e]				
Total recordable cases of injury and illness	68	68	130 - 330	330
Lost workday cases	27	27	50 - 130	130
Fatalities	0.066	0.066	0.12 - 0.32	0.32

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3.3.3.2 *Radiological Health Impacts to Workers*

F.3.3.3.2.1 Surface Facility Workers. During monitoring, surface facility workers would be involved in two types of activities with the potential for worker exposure. They are (a) the decontamination operation after the completion of emplacement, and (b) support of subsurface monitoring and caretaking activities by surface facility workers. Surface facility workers providing support for the subsurface monitoring and caretaking activities would receive very little radiological dose in comparison to their counterparts involved in the subsurface monitoring and caretaking activities because the greatest source of radiation exposure would be in the subsurface areas.

Radiological health impacts for the workers involved in surface facility decontamination activities, which are the same for the Inventory Modules as those for the Proposed Action, are listed in Table F-27.

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Table F-55. Industrial hazard health and safety impacts to subsurface facility workers during the monitoring period.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	140	140	240 - 680	680
Lost workday cases	56	56	97 - 270	270
Fatalities	0.13	0.13	0.23 - 0.65	0.65
Noninvolved workers				
Total recordable cases of injury and illness	29	29	52 - 140	140
Lost workday cases	14	14	25 - 67	67
Fatalities	0.025	0.025	0.045 - 0.12	0.12
All workers[e]				
Total recordable cases of injury and illness	170	170	290 - 820	820
Lost workday cases	70	70	120 - 340	340
Fatalities	0.16	0.16	0.28 - 0.77	0.77

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3.3.3.2.2 Subsurface Facility Workers. There are three exposure components which contribute to radiological health impacts to subsurface facility workers during the monitoring and caretaking phase. They are exposure from radiation emanating from the waste packages, exposure from the ambient radiation emanating from the drift walls, and exposure from inhalation of radon-222 and its progeny which are present in the subsurface atmosphere. Exposures to the subsurface workers during the monitoring and caretaking phase for each of these three components are listed in Tables F-56, F-57, and F-58, respectively. Exposures to the maximally exposed worker were based on a maximum work period of 50 years for an individual worker when the length of the monitoring periods was longer than 50 years.

Table F-56. Radiological health impacts to subsurface facility workers from exposure to waste packages during the monitoring and caretaking period.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	10,000	10,000	10,000	10,000
Probability of latent cancer fatality	0.004	0.004	0.004	0.004
Collective dose (person-rem)	230	230	410 - 1,100	1,100
Number of latent cancer fatalities	0.092	0.092	0.16 - 0.44	0.44
Noninvolved worker				
Dose to maximally exposed worker (millirem)	400	400	400	400
Probability of latent cancer fatality	0.00016	0.00016	0.00016	0.00016
Collective dose (person-rem)	6.9	6.9	13 - 34	34
Number of latent cancer fatalities	0.0028	0.0028	0.0052 - 0.014	0.014
All workers[e]				
Collective dose (person-rem)	240	240	420 - 1,100	1,100
Number of latent cancer fatalities	0.096	0.096	0.17 - 0.44	0.44

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-57. Radiological health impacts to subsurface facility workers from ambient radiation exposure during the monitoring and caretaking period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	2,500	2,500	2,500	2,500
Probability of latent cancer fatality	0.001	0.001	0.001	0.001
Collective dose (person-rem)	230	230	400 - 1,100	1,100
Number of latent cancer fatalities	0.092	0.092	0.16 - 0.44	0.44
Noninvolved worker				
Dose to maximally exposed worker (millirem)	1,000	1,000	1,000	1,000
Probability of latent cancer fatality	0.0004	0.0004	0.0004	0.0004
Collective dose (person-rem)	17	17	31 - 84	84
Number of latent cancer fatalities	0.0068	0.0068	0.012 - 0.034	0.034
All workers[e]				
Collective dose (person-rem)	250	250	430 - 1,200	1,200
Number of latent cancer fatalities	0.1	0.1	0.17 - 0.48	0.48

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-58. Radiological health impacts to subsurface facility workers from radon exposure during the monitoring and caretaking period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	5,000	5,000	5,000	5,000
Probability of latent cancer fatality	0.002	0.002	0.002	0.002
Collective dose (person-rem)	470	470	810 - 2,300	2,300
Number of latent cancer fatalities	0.19	0.19	0.32 - 0.92	0.92
Noninvolved worker				
Dose to maximally exposed worker (millirem)	400	400	400	400
Probability of latent cancer fatality	0.00016	0.00016	0.00016	0.00016
Collective dose (person-rem)	6.9	6.9	13 - 34	34
Number of latent cancer fatalities	0.0028	0.0028	0.0052 - 0.014	0.014
All workers[e]				
Collective dose (person-rem)	480	480	820 - 2,300	2,300
Number of latent cancer fatalities	0.19	0.19	0.33 - 0.92	0.92

a. Source: Exposure data from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

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F.3.3.3.3 *Summary of Health Impacts for the Monitoring and Caretaking Period*

Tables F-59 and F-60 present the occupational and radiological impacts, respectively, to all workers from monitoring and caretaking activities. In each table, impacts are presented for the higher-temperature uncanistered and dual-purpose canister packaging scenarios; in addition, the range of impacts for the lower-temperature uncanistered packaging scenario is presented along with the impacts for the dual-purpose canister packaging scenario with long-term ventilation.

Table F-59. Summary of industrial hazard health and safety impacts to facility workers during monitoring period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	290	270	450 - 1,100	1,100
Lost workday cases	120	110	180 - 440	430
Fatalities	0.28	0.26	0.43 - 1.1	1
Noninvolved workers				
Total recordable cases of injury and illness	51	49	74 - 160	160
Lost workday cases	25	24	36 - 78	77
Fatalities	0.045	0.043	0.065 - 0.14	0.14
All workers[e]				
Total recordable cases of injury and illness	340	320	520 - 1,300	1,300
Lost workday cases	150	130	220 - 520	510
Fatalities	0.33	0.3	0.5 - 1.2	1.1

a. Sources: Calculated using impact rates from Tables F-24, F-54, and F-55.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-60. Summary of radiological health impacts to workers from all activities during monitoring period.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	18,000	18,000	18,000	18,000
Probability of latent cancer fatality	0.0072	0.0072	0.0072	0.0072
Collective dose (person-rem)	990	980	1,700 - 4,500	4,500
Number of latent cancer fatalities	0.4	0.39	0.68 - 1.8	1.8
Noninvolved worker				
Dose to maximally exposed worker (millirem)	1,800	1,800	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072	0.00072	0.00072
Collective dose (person-rem)	31	31	56 - 150	150
Number of latent cancer fatalities	0.012	0.012	0.022 - 0.06	0.06
All workers[e]				
Collective dose (person-rem)	1,000	1,000	1,800 - 4,700	4,700
Number of latent cancer fatalities	0.4	0.4	0.72 - 1.9	1.9

a. Sources: Calculated using impact rates from Tables F-27, F-56, F-57, and F-58.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3.3.4 Closure Phase

F.3.3.4.1 *Health and Safety Impacts to Workers from Industrial Hazards*

This section details health and safety impacts to workers from industrial hazards common to the workplace for the closure phase. The impacts would consist of two components—impacts to surface workers supporting the closure operations, and impacts to subsurface workers during the closure phase. These impacts are listed in Tables F-61 and F-62, respectively.

Table F-61. Industrial hazard health and safety impacts to surface facility workers during the closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	180	160	180	160
Lost workday cases	85	75	85	75
Fatalities	0.085	0.075	0.085	0.075
Noninvolved workers				
Total recordable cases of injury and illness	37	32	37	32
Lost workday cases	18	16	18	16
Fatalities	0.032	0.028	0.032	0.028
All workers[e]				
Total recordable cases of injury and illness	220	190	220	190
Lost workday cases	100	91	100	91
Fatalities	0.12	0.1	0.12	0.1

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-62. Health and safety impacts to subsurface facility workers from industrial hazards during the closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	170	170	220 - 420	230
Lost workday cases	83	83	100 - 200	110
Fatalities	0.083	0.083	0.1 - 0.2	0.11
Noninvolved workers				
Total recordable cases of injury and illness	18	18	22 - 46	24
Lost workday cases	8.6	8.6	11 - 22	12
Fatalities	0.016	0.016	0.02 - 0.04	0.021
All workers[e]				
Total recordable cases of injury and illness	190	190	240 - 470	250
Lost workday cases	92	92	110 - 220	120
Fatalities	0.099	0.099	0.12 - 0.24	0.13

a. Source: Calculated using impact rates from Table F-4.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3.3.4.2 *Radiological Health Impacts to Workers*

Radiological health impact to workers from closure activities are the sum of the following components:

- Radiological health impacts to subsurface workers from radiation emanating from the waste packages during the closure phase (Table F-63)
- Radiological impacts to subsurface workers from the ambient radiation field in the drifts during the closure phase (Table F-64)
- Radiological impacts to subsurface workers from inhalation of radon-222 in the drift atmosphere during the closure phase (Table F-65)

Table F-63. Radiological health impacts to subsurface facility workers from waste package exposure during closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	7,200	7,200	9,700 - 16,000	10,000
Probability of latent cancer fatality	0.0029	0.0029	0.0039 - 0.0064	0.004
Collective dose (person-rem)	320	320	410 - 620	430
Number of latent cancer fatalities	0.13	0.13	0.16 - 0.25	0.17
Noninvolved worker				
Dose to maximally exposed worker (millirem)	96	96	120 - 180	130
Probability of latent cancer fatality	0.000038	0.000038	0.000048 - 0.000072	0.000052
Collective dose (person-rem)	4.3	4.3	5.4 - 11	5.8
Number of latent cancer fatalities	0.0017	0.0017	0.0022 - 0.0044	0.0023
All workers[e]				
Collective dose (person-rem)	320	320	420 - 630	440
Number of latent cancer fatalities	0.13	0.13	0.17 - 0.25	0.18

a. Source: Exposure rates from Table F-6.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Because the surface facilities would be largely decontaminated at the beginning of the monitoring period (the exception would be a small facility retained to handle an operations emergency), radiological health impacts to surface facility workers during closure would be small in comparison to those to the subsurface facility workers and so are not included here. DOE estimated exposures to subsurface workers from waste packages by increasing those from the Proposed Action by the ratio of the length of closure phases.

F.3.3.4.3 *Summary of Impacts for Closure Phase*

Tables F-66 and F-67 present the occupational and radiological impacts, respectively, to all workers from activities performed during the closure phase. In each table, impacts are presented for the higher-temperature uncanistered and dual-purpose canister packaging scenarios; in addition, the range of impacts for the lower-temperature uncanistered packaging scenario is presented along with the impacts for the dual-purpose canister packaging scenario with long-term ventilation without aging.

Table F-64. Radiological health impacts to subsurface facility workers from ambient radiation exposure during closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	600	600	750 - 1,200	800
Probability of latent cancer fatality	0.00024	0.00024	0.0003 - 0.00048	0.00032
Collective dose (person-rem)	140	140	180 - 350	190
Number of latent cancer fatalities	0.056	0.056	0.072 - 0.14	0.076
Noninvolved worker				
Dose to maximally exposed worker (millirem)	240	240	300 - 460	320
Probability of latent cancer fatality	0.000096	0.000096	0.00012 - 0.00018	0.00013
Collective dose (person-rem)	11	11	14 - 28	14
Number of latent cancer fatalities	0.0044	0.0044	0.0056 - 0.011	0.0056
All workers[e]				
Collective dose (person-rem)	150	150	190 - 380	200
Number of latent cancer fatalities	0.06	0.06	0.076 - 0.15	0.08

a. Source: Exposure rates from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-65. Radiological health impacts to subsurface facility workers from radon exposure during closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Full-time equivalent worker years[e]	2,900	2,900	3,600 - 6,900	3,800
Dose to maximally exposed worker (millirem)	240	240	300 - 460	320
Probability of latent cancer fatality	0.000096	0.000096	0.00012 - 0.00018	0.00013
Collective dose (person-rem)	57	57	71 - 140	76
Number of latent cancer fatalities	0.023	0.023	0.028 - 0.056	0.03
Noninvolved worker				
Full-time equivalent worker years[e]	540	540	680 - 1,400	720
Dose to maximally exposed worker (millirem)	96	96	120 - 180	130
Probability of latent cancer fatality	0.000038	0.000038	0.000048 - 0.000072	0.000052
Collective dose (person-rem)	4.3	4.3	5.4 - 11	5.8
Number of latent cancer fatalities	0.0017	0.0017	0.0022 - 0.0044	0.0023
All workers[f]				
Full-time equivalent worker years	3,400	3,400	4,300 - 8,300	4,500
Collective dose (person-rem)	61	61	76 - 150	82
Number of latent cancer fatalities	0.024	0.024	0.030 - 0.06	0.033

a. Source: Exposure rates from Table F-7.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Source: Table F-42.
f. Totals might differ from sums of values due to rounding.

Table F-66. Summary of industrial hazard health and safety impacts to facility workers during closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	350	330	400 - 600	390
Lost workday cases	170	160	190 - 280	180
Fatalities	0.17	0.16	0.19 - 0.28	0.18
Noninvolved workers				
Total recordable cases of injury and illness	54	50	59 - 82	56
Lost workday cases	26	24	29 - 40	27
Fatalities	0.048	0.044	0.052 - 0.072	0.049
All workers[e]				
Total recordable cases of injury and illness	400	380	460 - 680	450
Lost workday cases	200	180	220 - 320	210
Fatalities	0.22	0.2	0.24 - 0.35	0.23

a. Sources: Tables F-61 and F-62.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-67. Summary of radiological health impacts to workers from all activities during closure phase.[a,b]

Worker group	Operating mode			
	Higher-temperature		Lower-temperature	
	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	8,000	8,000	11,000 - 18,000	11,000
Probability of latent cancer fatality	0.0032	0.0032	0.0044 - 0.0072	0.0044
Collective dose (person-rem)	520	520	660 - 1,100	700
Number of latent cancer fatalities	0.21	0.21	0.26 - 0.44	0.28
Noninvolved worker				
Dose to maximally exposed worker (millirem)	430	430	540 - 830	580
Probability of latent cancer fatality	0.00017	0.00017	0.00022 - 0.00033	0.00023
Collective dose (person-rem)	19	19	24 - 50	26
Number of latent cancer fatalities	0.0076	0.0076	0.0096 - 0.02	0.01
All workers[e]				
Collective dose (person-rem)	540	540	680 - 1,200	730
Number of latent cancer fatalities	0.22	0.22	0.27 - 0.48	0.29

a. Sources: Tables F-63, F-64, and F-65.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.3.3.5 Summary of Impacts for All Repository Phases

Tables F-68 and F-69 present the occupational and radiological impacts, respectively, to all workers from all activities performed during all phases. In each table, impacts are presented for the higher-temperature uncanistered and dual-purpose canister packaging scenarios; in addition, the range of impacts for the lower-temperature uncanistered packaging scenario is presented along with the impacts for the dual-purpose canister packaging scenario with long-term ventilation without aging.

Table F-68. Summary of industrial hazard health and safety impacts to facility workers during all phases.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved workers				
Total recordable cases of injury and illness	2,900	2,400	3,400 - 4,000	3,300
Lost workday cases	1,400	1,200	1,600 - 1,900	1,600
Fatalities	2.1	1.6	2.4 - 3.1	2.4
Noninvolved workers				
Total recordable cases of injury and illness	640	680	690 - 830	800
Lost workday cases	310	340	340 - 410	390
Fatalities	0.61	0.65	0.65 - 0.78	0.75
All workers[e]				
Total recordable cases of injury and illness	3,500	3,100	4,100 - 4,800	4,100
Lost workday cases	1,700	1,500	1,900 - 2,300	2,000
Fatalities	2.7	2.3	3.1 - 3.9	3.2

a. Sources: Tables F-12, F-52, F-59, and F-66.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

Table F-69. Summary of radiological health impacts to workers from all activities during all phases.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Worker group	UC[c]	DPC[d]	UC (range)	DPC
Involved worker				
Dose to maximally exposed worker (millirem)	24,000	24,000	24,000 - 33,000	24,000
Probability of latent cancer fatality	0.0096	0.0096	0.0096 - 0.013	0.0096
Collective dose (person-rem)	14,000	9,900	16,000 - 20,000	14,000
Number of latent cancer fatalities	5.6	4.0	6.4 - 8	5.6
Noninvolved worker				
Dose to maximally exposed worker (millirem)	2,400	2,400	2,400	2,400
Probability of latent cancer fatality	0.00096	0.00096	0.00096	0.00096
Collective dose (person-rem)	270	270	330 - 410	400
Number of latent cancer fatalities	0.11	0.11	0.13 - 0.16	0.16
All workers[e]				
Collective dose (person-rem)	14,000	10,000	16,000 - 20,000	14,000
Number of latent cancer fatalities	5.6	4	6.4 - 8	5.6

a. Source: Sum of values from Tables F-11, F-53, F-60, and F-67.
b. Numbers are rounded to two significant figures.
c. UC = uncanistered packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Totals might differ from sums of values due to rounding.

F.4 Worker Human Health and Safety Impact Analysis for the Retrieval Contingency

Nuclear Regulatory Commission regulations state that the period for which DOE must maintain the ability to retrieve waste is at least 50 years after the start of emplacement operations [10 CFR 60.111(b)]. Although DOE does not anticipate retrieval and it is not part of the Proposed Action, the Department would maintain the ability to retrieve the waste for at least 100 years and possibly for as long as 300 years after the start of emplacement. Factors that could lead to a decision to retrieve the waste would be (1) to protect the public health and safety or the environment or (2) to recover resources from spent nuclear fuel. This EIS evaluates retrieval as a contingency action and describes potential impacts should it occur. The analysis assumes that under this contingency DOE would retrieve all the waste associated with the Proposed Action and would place it on surface storage pads pending future decisions about its ultimate disposition.

The analysis of health and safety impacts to workers divided the retrieval period into two subperiods, as follows:

- First, a construction subperiod in which DOE would (1) build the surface facilities necessary to handle and enclose retrieved waste packages in concrete storage units in preparation for placement on concrete storage pads, and (2) construct the concrete storage pads.

  No radioactive materials would be involved in the construction subperiod, so health and safety impacts would be limited to those associated with industrial hazards in the workplace. DOE expects this subperiod would last 2 to 3 years, although construction of the concrete storage pads probably would continue on an as-needed basis during most of the operations subperiod. The analysis assumed a 3-year period.

- Second, an operations subperiod during which the waste packages would be retrieved and moved to the Waste Retrieval Transfer Building. Surface facility workers would unload the waste package from the transfer vehicle and place it on a concrete base. The package and concrete base would then be enclosed in a concrete storage unit that would be placed on the concrete storage pad. The analysis assumed an 11-year period.

This section discusses the methodologies and data used to estimate human health and safety impacts resulting from the retrieval contingency. Section F.4.1 describes the methods DOE used to estimate impacts. Section F.4.2 contains tabulations of the detailed data used in the impact calculations and references to the data sources. Section F.4.3 contains detailed tabulations of the results.

F.4.1 METHODOLOGY FOR CALCULATING HUMAN HEALTH AND SAFETY IMPACTS

DOE used the methodology summarized in Section F.2.1 to estimate health and safety impacts for the retrieval contingency. This involved assembling data for the number of full-time equivalent workers for each retrieval activity. These numbers were used with statistics on the likelihood of an impact (industrial hazards), or the estimated radiological dose rate in the worker environment, to calculate health and safety impacts. The way in which the input data were combined to calculate health and safety impacts is described in more detail in Section F.2.1. Some of the input data in the retrieval impact calculations are different from those for the Proposed Action, as described in the next section.

F.4.2 DATA SOURCES AND TABULATIONS

F.4.2.1 Full-Time Equivalent Worker-Year Estimates for the Retrieval Contingency

This analysis divides the repository workforce into two groups—involved and noninvolved workers (see Section F.2 for definitions of involved and noninvolved workers).

Table F-70 lists the number of full-time equivalent work years for the two subperiods of the retrieval operation and the sources of the numbers. Each full-time equivalent worker year represents 2,000 work hours, the hours assumed to be worked in a normal work year. The full-time equivalent worker-year estimates are independent of repository operating mode.

Table F-70. Full-time equivalent worker-year estimates for retrieval.

Subperiod and worker group	Length of subperiod (years)	Full-time equivalent worker years[a]
Surface facilities, construction[b]	3	
Involved		1,300
Noninvolved		500
Surface facilities, retrieval support[c]	11	
Involved		320
Noninvolved		870
Subsurface facility retrieval operations[d]	11	
Involved		810
Noninvolved		180
Total		**4,000**

a. Numbers are rounded to two significant figures.
b. Source: DIRS 154758-Lane (2000, all).
c. Source: DIRS 152010-CRWMS M&O (2000, Table I-3, p. I-20).
d. Source: DIRS 150941-CRWMS M&O (2000, Table 6-29, p. 6-20).

F.4.2.2 Statistics on Health and Safety Impacts from Industrial Hazards in the Workplace

For the retrieval contingency, DOE used the same set of statistics on health and safety impacts from industrial hazards common to the workplace that were used for the Proposed Action (70,000 MTHM) (see Table F-4). The specific statistics that were applied to the retrieval contingency subphases are listed in Table F-71.

F.4.2.3 Estimated Radiological Exposure Rates and Times for the Retrieval Contingency

DOE used the same set of worker exposure rate data as those used for evaluating radiological worker impacts for the Proposed Action. Table F-72 presents the specific application of this data to the retrieval contingency subphases. The source of the information is also referenced. The rates used in the analysis did not take into account radioactive decay for the period between emplacement and retrieval.

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Table F-71. Statistics for industrial hazard impacts for retrieval.

Subperiod and worker group	Total recordable incidents (rate per 100 FTEs)[a]	Lost workday cases (rate per 100 FTEs)[a]	Fatalities (rate per 100,000 FTEs)[a]
Construction, surface workers[b]			
Involved	6.1	2.9	2.9
Noninvolved	3.3	1.6	
Retrieval, surface workers[c]			2.9
Involved	3.0	1.2	
Noninvolved	3.3	1.6	
Retrieval, subsurface workers[d]			2.9
Involved	3.0	1.2	
Noninvolved	3.3	1.6	

a. FTE = full-time equivalent worker years.
b. Source: Data Set 4, Section F.2.2.
c. Source: Data Set 1, Section F.2.2.
d. Source: Data Set 3, Section F.2.2.

Table F-72. Radiological doses and exposure data used to calculate worker exposures during retrieval.[a]

Subperiod and worker group	Source of exposure	Occupancy factor for exposure rate (fraction of 8-hour workday)	Annual dose (millirem)	Source[b]
Construction				
Surface				
Involved	None			
Noninvolved	None			
Operations				
Surface				
Involved	Waste package	1.0	25	(1)
Noninvolved	Waste package	1.0	0	(1)
Subsurface				
Involved	Waste package	1.0	600	(2)
	Radon-222[c]	1.0	20	Table F-2
	Drift ambient	1.0	50	Section F.1.6
Noninvolved	Waste package	0.04 (0.4 for 10% of workers)	200	(3)
	Radon-222	0.4	20	Tables F-2, F-4, and F-5
	Drift ambient	0.4	50	Sections F.1.6, F.4, and F.5

a. External exposures include radiation from spent nuclear fuel and high-level radioactive waste packages to surface and subsurface workers, the ambient exposure to subsurface workers from naturally occurring radiation in the drift walls, and subsurface worker exposure from inhalation of radon-222.
b. Sources:
(1) DIRS 152010-CRWMS M&O (2000, Table I-3, p. I-20).
(2) Table F-6.
(3) Table F-2; DIRS 104536-Rasmussen (1999, all).
c. Exposure rates from inhalation of radon-222 are assumed to be the same as those for the construction phase.

F.4.3 DETAILED RESULTS FOR THE RETRIEVAL CONTINGENCY

F.4.3.1 Construction Phase

F.4.3.1.1 *Human Health and Safety Impacts to Workers from Industrial Hazards*

The construction phase would entail only surface-facility activities. Table F-73 summarizes health and safety impacts to workers from industrial hazards during construction. There would be no radiological sources present during surface facility construction activities for retrieval and, hence, no radiological health and safety impacts to workers.

Table F-73. Industrial hazard health and safety impacts to workers during construction.[a,b]

Worker group	Impacts
Involved	
Total recordable cases of injury and illness	80
Lost workday cases	38
Fatalities	0.04
Noninvolved	
Total recordable cases of injury and illness	16
Lost workday cases	8
Fatalities	0.01
All workers (totals)	
Total recordable cases of injury and illness	96
Lost workday cases	46
Fatalities	0.05

a. Source: Calculated using impact rates from Table F-71.
b. Numbers are rounded to two significant figures.

F.4.3.2 Operations Period

F.4.3.2.1 *Health and Safety Impacts to Workers from Industrial Hazards*

Chapter 4, Table 4-55, summarizes health and safety impacts to workers from industrial hazards common to the workplace for the retrieval operations period. The impacts in that table consist of two components—health impacts to surface workers and health impacts to subsurface workers. Tables F-74 and F-75 list health impacts from industrial hazards during retrieval operations for these two components, surface and subsurface workers, respectively.

F.4.3.2.2 *Radiological Health and Safety Impacts to Workers*

Potential radiological health impacts to workers during the operations period of retrieval consist of the following components:

- Impacts to surface facility workers involved in handling the waste packages and placing them in concrete storage units
- Impacts to subsurface facilities workers from direct radiation emanating from the waste packages

- Impacts to subsurface workers from inhalation of radon-222 in the atmosphere of the drifts
- Impacts to subsurface workers from ambient radiation from naturally occurring radionuclides in the drift walls

Tables F-76 and F-77 list potential radiological health impacts for each of these component parts.

Table F-74. Industrial hazard health and safety impacts to surface facility workers during retrieval operations.[a,b]

Worker group	Impacts
Involved	
Total recordable cases of injury and illness	10
Lost workday cases	4
Fatalities	0.009
Noninvolved	
Total recordable cases of injury and illness	29
Lost workday cases	14
Fatalities	0.03
All workers (totals)[c]	
Total recordable cases of injury and illness	39
Lost workday cases	18
Fatalities	0.039

a. Source: Impact rates from Table F-71.
b. Numbers are rounded to two significant figures.
c. Totals might differ from sums of values due to rounding.

Table F-75. Industrial hazard health and safety impacts to subsurface facility workers during retrieval operations.[a,b]

Worker group	Impacts
Involved	
Total recordable cases of injury and illness	24
Lost workday cases	11
Fatalities	0.02
Noninvolved	
Total recordable cases of injury and illness	6
Lost workday cases	3
Fatalities	0.01
All workers (totals)[c]	
Total recordable cases of injury and illness	30
Lost workday cases	14
Fatalities	0.03

a. Source: Impact rates from Table F-71.
b. Numbers are rounded to two significant figures.
c. Totals might differ from sums of values due to rounding.

Table F-76. Radiological health impacts to surface facility workers from waste handling during retrieval operations.[a]

Worker group	Impacts
Involved	
Maximally exposed individual dose (millirem)	280
Latent cancer fatality probability for maximally exposed individual	0.0001
Collective dose (person-rem)	8
Latent cancer fatality incidence for overall worker group	0.003
Noninvolved	
Maximally exposed individual dose (millirem)	0
Latent cancer fatality probability for maximally exposed individual	0
Collective dose (person-rem)	0
Latent cancer fatality incidence for overall worker group	0
All workers (totals)[b]	
Collective dose (person-rem)	8
Latent cancer fatality	0.003

a. Source: Exposure rate data from Table F-72.
b. Totals might differ from sums due to rounding.

Table F-77. Components of radiological health impacts to subsurface workers during retrieval operations.[a]

Worker group	Source of exposure			
	Waste packages	Ambient	Radon-222 inhalation	Total[b]
Involved				
Maximally exposed individual dose (millirem)	5,200	550	1,400	5,900
Latent cancer fatality probability for maximally exposed individual	0.002	0.0002	0.0009	0.002
Collective dose (person-rem)	66	41	16	120
Latent cancer fatality incidence for overall worker group	0.08	0.02	0.04	0.05
Noninvolved				
Maximally exposed individual dose (millirem)	88	220	130	440
Latent cancer fatality probability for maximally exposed individual	0.00004	0.00009	0.00005	0.0002
Collective dose (person-rem)	1	4	1	4
Latent cancer fatality incidence for overall worker group	0.0004	0.001	0.0006	0.002
All workers (totals)[c]				
Collective dose (person-rem)	67	45	17	130
Latent cancer fatality incidence for overall worker group	0.08	0.02	0.04	0.05

a. Source: Exposure data from Table F-72.
b. Totals might differ from sums due to rounding.
c. Source: FTE values from Table F-70.

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Appendix G

Air Quality

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APPENDIX G. AIR QUALITY

Potential releases of nonradiological and radiological pollutants associated with the construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository could affect the air quality in the surrounding region. This appendix discusses the methods and additional data and intermediate results that the U.S. Department of Energy (DOE) used to estimate impacts from potential releases to air. Results for the Proposed Action are presented in Chapter 4, Section 4.1.2, and in Chapter 8, Section 8.2.2 for Inventory Modules 1 and 2.

Nonradiological pollutants can be categorized as hazardous and toxic air pollutants, criteria pollutants, or other substances of particular interest. Repository activities would cause the release of no or very small quantities of hazardous and toxic pollutants; therefore, these pollutants were not considered in the analysis. Concentrations of six criteria pollutants are regulated under the National Ambient Air Quality Standards (40 CFR Part 50) established by the Clean Air Act. This analysis evaluated releases and potential impacts of four of these pollutants—carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10})—quantitatively. It also considered the two other criteria pollutants—lead and ozone—and particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$), a new limit, which has not yet been implemented. In addition, this analysis considers potential releases to air of cristobalite, a form of crystalline silica that can cause silicosis and is a potential carcinogen. These pollutants could be released during all project phases. Section G.1 describes the methods DOE used to calculate impacts from releases of criteria pollutants and cristobalite.

Radionuclides that repository-related activities could release to the atmosphere include the noble gas krypton-85 from spent nuclear fuel handling during the operation and monitoring phase, and naturally occurring radon-222 and its decay products from ventilation of the subsurface facility during all project phases. Other radionuclides would not be released or would be released in such small quantities they would result in very small impacts to air quality. Such radionuclides are not discussed further in this appendix. Section G.2 describes the methods DOE used to calculate impacts of radionuclide releases.

G.1 Nonradiological Air Quality

This section describes the methods DOE used to analyze potential impacts to air quality at the proposed Yucca Mountain Repository from releases of nonradiological air pollutants during the construction, operation and monitoring, and closure phases, and a retrieval scenario. It also describes intermediate results for various repository activities. Table G-1 lists the six criteria pollutants regulated under the National Ambient Air Quality Standards or the Nevada Administrative Code along with their regulatory limits and the periods over which pollutant concentrations are averaged. The criteria pollutants addressed quantitatively in this section are nitrogen dioxide, sulfur dioxide, particulate matter 10 micrometers or less in aerodynamic diameter (PM_{10}), and carbon monoxide. No sources of airborne lead would occur at the repository, so evaluations and results are not presented. Particulate matter 2.5 micrometers or less in aerodynamic diameter ($PM_{2.5}$) and ozone are discussed below, as is cristobalite, a mineral occurring naturally in the subsurface rock at Yucca Mountain.

The purpose of the ozone standard is to control the ambient concentration of ground-level ozone, not naturally occurring ozone in the upper atmosphere. Ozone is not emitted directly into the air; rather, it is formed when volatile organic compounds react in the presence of sunlight. Nitrogen dioxides are also important precursors to ozone. Small quantities of volatile organic compounds would be released from repository activities; the peak annual release would be about 700 kilograms (1,500 pounds) (DIRS 152010-CRWMS M&O 2000, Table 6-2, p. 52). Because Yucca Mountain is in an attainment area for ozone, the analysis compared the estimated annual release to the Prevention of Significant Deterioration

Table G-1. Criteria pollutants and regulatory limits.

Pollutant	Period	Regulatory limit[a] Parts per million	Micrograms per cubic meter
Nitrogen dioxide	Annual	0.053	100
Sulfur dioxide	Annual	0.03	80
	24-hour	0.14	365
	3-hour	0.50	1,300
Carbon monoxide	8-hour	9	10,000
	1-hour	35	40,000
PM_{10}	Annual		50
	24-hour		150
$PM_{2.5}$[b]	Annual		15
	24-hour		65
Ozone	8-hour	0.08	157
	1-hour	0.12	235
Lead	Quarterly		1.5

a. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391. Not all limits are provided in parts per million.
b. Standard not yet implemented.

of Air Quality emission threshold for volatile organic compounds from stationary sources (40 CFR 52.21). The volatile organic compound emission threshold is 35,000 kilograms (77,000 pounds) per year, so the peak annual release from the repository would be well below this level. Accordingly, the analysis did not address volatile organic compounds and ozone further, although this does not preclude future, more detailed analyses if estimates of volatile organic compound emissions change.

The U.S. Environmental Protection Agency revised the primary and secondary standards for particulate matter in 1997 (62 *FR* 38652, July 18, 1997), establishing annual and 24-hour $PM_{2.5}$ standards at 15 micrograms per cubic meter and 65 micrograms per cubic meter, respectively. Primary standards set limits to protect public health, including the health of "sensitive" populations. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings. Because the new particulate standard will regulate $PM_{2.5}$ for the first time, the agency has allowed 5 years for the creation of a national monitoring network and the analysis of collected data to help develop state implementation plans. The new $PM_{2.5}$ standards have not been implemented and the imposition of local area controls will not be required until 2005. By definition, $PM_{2.5}$ levels can be no more than, and in the real world are always substantially less than, PM_{10} levels. In general, $PM_{2.5}$ levels would be approximately one-third of the PM_{10} levels. As the analysis for PM_{10} shows, even the maximum PM_{10} levels that could be generated by the Proposed Action are substantially below the $PM_{2.5}$ standards. Thus, although no detailed $PM_{2.5}$ analysis has been conducted, the PM_{10} analysis can be regarded as a surrogate for a $PM_{2.5}$ analysis and illustrates that potential $PM_{2.5}$ levels would be well below applicable regulatory standards.

Cristobalite, one of several naturally occurring crystalline forms of silica (silicon dioxide), is a major mineral constituent of Yucca Mountain tuffs (DIRS 104523-CRWMS M&O 1999, p. 4-81). Prolonged high exposure to crystalline silica can cause silicosis, a disease characterized by scarring of lung tissue. An increased cancer risk to humans who already have developed adverse noncancer effects from silicosis has been shown, but the cancer risk to otherwise healthy individuals is not clear (DIRS 103243-EPA 1996, p. 1-5). Cristobalite is principally a concern for involved workers because it could be inhaled during subsurface excavation operations. Appendix F, Section F.1.2, contains additional information on crystalline silica.

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While there are no limits for exposure of the general public to cristobalite, there are limits to workers for exposure (29 CFR 1910.1000). Therefore, this analysis used a comparative benchmark of 10 micrograms per cubic meter, based on a cumulative lifetime exposure of 1,000 micrograms per cubic meter multiplied by years (that is, the average annual exposure concentration times the number of years exposed). At this level, an Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, pp. 1-5 and 7-5) states that there is a less than 1-percent chance of silicosis. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter, which was rounded down to 10 micrograms per cubic meter to establish the benchmark.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this rock pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). Using the parent rock percentage probably overestimated the airborne cristobalite concentration, because studies of both ambient and occupational airborne crystalline silica have shown that most of this airborne material is coarse and not respirable and that larger particles deposit rapidly on the surface (DIRS 103243-EPA 1996, p. 3-26).

G.1.1 COMPUTER MODELING AND ANALYSIS

DOE used the Industrial Source Complex computer program to estimate the annual and short-term (24-hour or less) air quality impacts at the proposed Yucca Mountain Repository. The Department has used this program in recent EISs (DIRS 101802-DOE 1995, all; DIRS 101814-DOE 1997, all; DIRS 101816-DOE 1997, all) to estimate nonradiological air quality impacts. The program contains both a short-term model (which uses hourly meteorological data) and a long-term model (which uses joint frequency meteorological data). The program uses steady-state Gaussian plume models to estimate pollutant concentrations from a variety of sources associated with industrial complexes (DIRS 103242-EPA 1995, all). This modeling approach assumes that (1) the time-averaged pollutant concentration profiles at any distance downwind of the release point may be represented by a Gaussian (normal) distribution in both the horizontal and vertical directions; and (2) the meteorological conditions are constant (persistent) over the time of transport from source to receptor. The Industrial Source Complex program is appropriate for either flat or rolling terrain, and for either urban or rural environments. The Environmental Protection Agency has approved this program for specific regulatory applications. Input requirements for the program include source configuration and pollutant emission parameters. The short-term model was used in this analysis to estimate all nonradiological air quality impacts and uses hourly meteorological data that include wind speed, wind direction, and stability class to compute pollutant transport and dispersion.

Because the short-term pollutant concentrations were based on annual usage or release parameters, conversion of annual parameter values to short-term values depended on the duration of the activity. Many of the repository activities were assumed to have a schedule of 250 working days per year, so the daily release would be the annual value divided by 250.

In many cases, site- or activity-specific information was not available for estimating pollutant emissions at the Yucca Mountain site. In these cases, generic information was used and conservative assumptions were made that tended to overestimate actual air concentrations.

As noted in Section G.1, the total nonradiological air quality impacts are described in Chapter 4, Section 4.1.2, for the Proposed Action and in Chapter 8, Section 8.2.2, for the inventory modules. These impacts are the sum of air quality impacts from individual sources and activities that take place during each of the project phases and that are discussed later in this section (for example, dust emissions from the concrete batch facility during the construction phase). The maximum air quality impact (that is, air concentration) resulting from individual sources or activities could occur at different land withdrawal area boundary locations depending on the release period and the regulatory averaging time (see Section G.1.3). These maximums generally occur in a westerly or southerly direction. The total nonradiological air quality impacts presented in Sections 4.1.2 and 8.2.2 are the sum of the calculated maximum concentrations regardless of direction. Therefore, the values presented would be larger than the actual sum of the concentrations for a particular distance and direction. This approach was selected to simplify the presentation of air quality results.

G.1.2 LOCATIONS OF HYPOTHETICALLY EXPOSED INDIVIDUALS

The location of the public maximally exposed individual was determined by calculating the maximum ground-level pollutant concentrations. Because unrestricted public access would be limited to the site boundary, the analysis assumed that a hypothetical individual would be present at one point on the site boundary during the entire averaging time of the regulatory limit (Table G-1).

Table G-2 lists the distances from the North and South Portals to the land withdrawal area boundary where maximally exposed individual locations were evaluated. The table does not list all directions because the land withdrawal area boundaries would not be accessible to members of the public in some directions (restricted access areas of the Nevada Test Site and Nellis Air Force Range). The distance to the nearest unrestricted public access in these directions would be so large that there would be no air quality impacts. For the east to south-southeast directions, the distances to the land withdrawal area boundary would be large, but the terrain is such that plumes traveling in these directions tend to enter Fortymile Wash and turn south. The southern land withdrawal area boundary would be the location of a maximally exposed individual with long-term (1-year) unrestricted access, such as a resident. The short-term (1 to 24 hours) maximally exposed individual location would be the western land withdrawal area boundary, where an individual such as a hiker or hunter could be located. No long-term access (that is, residency) could occur at this location on government-owned land. The access periods evaluated are based on the exposure periods listed in Table G-1.

Table G-2. Distance to the nearest point of unrestricted public access (kilometers).[a,b,c]

Direction	From North Portal	From South Portal
Northwest	14	15
West-northwest	12	12
West	11	11
West-southwest	14	12
Southwest	18	16
South-southwest	23	19
South	21	18
South-southeast	21	19
Southeast	22	24

a. Source: Derived from (DIRS 104493-YMP 1997, all and DIRS 153849-DOE 2001, p. l-21)
b. Numbers are rounded to two significant figures.
c. To convert kilometers to miles, multiply by 0.62137.

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G.1.3 METEOROLOGICAL DATA AND REFERENCE CONCENTRATIONS

DOE estimated the concentrations of criteria pollutants in the region of the repository by using the Industrial Source Complex program and site-specific meteorological data for 1993 to 1997 from air quality and meteorology monitoring Site 1 (DIRS 102877-CRWMS M&O 1999, electronic addendum). Site 1 is less than 1 kilometer (0.6 mile) south of the proposed North Portal surface facility location.

Similar topographic exposure leads to similar prevailing northerly and southerly winds at both locations. DOE used Site 1 data because an analysis of the data collected at all the sites showed that site to be most representative of the surface facilities (DIRS 102877-CRWMS M&O 1999, p. 7). Wind speed data are from the 10-meter (33-foot) level, as are atmospheric stability data, using the night-adjusted sigma-theta method (DIRS 101822-EPA 1987, pp. 6-20 to 6-32). Mixing height measurements were not available for Yucca Mountain so the analysis assumed a mixing height of approximately 140 meters (470 feet), which is one-tenth of the 1,420 meters (4,700 feet) mixing-layer depth for Desert Rock, Nevada. Desert Rock is the nearest upper air meteorological station, about 44 kilometers (27 miles) east-southeast near Mercury, Nevada. The average mixing height at Desert Rock was divided by 10 to simulate the mixing height during very stable conditions, which is when the highest concentrations from a ground-level source would normally occur. All nonradiological pollutant releases were assumed to come from ground-level point sources. Both of these conservative assumptions, made because of a lack of site-specific information, tend to overestimate actual air concentrations. Fugitive dust emissions could be modeled as an area source, but the distance from the source to the exposure location would be large [more than 10 kilometers (6 miles)] so a point source provides a good approximation. Some sources would have plume rise, such as boiler emissions, but this was not considered because there is inadequate information to characterize the rise.

The analysis estimated unit release concentrations at the land withdrawal area boundary points of maximum exposure for ground-level point-source releases. The concentrations were based on release rates of 1 gram (0.04 ounce) per second for each of the five regulatory limit averaging times (annual, 24-hour, 8-hour, 3-hour, or 1-hour). Various activities at the Yucca Mountain site could result in pollutants being released over four different periods in a 24-hour day [continuously, 8-hour, 12-hour (two 6-hour periods), or 3-hour]. Eleven combinations of release periods and regulatory limit averaging times would be applicable to activities at the Yucca Mountain site.

The analysis assumed that the 8-hour pollutant releases would occur from 8 a.m. to 4 p.m. and to be zero for all other hours of the day. Similarly, it assumed that the 3-hour releases would occur from 9 a.m. to 12 p.m. and to be zero for all other hours. The 12-hour release would occur over two 6-hour periods, assumed to be from 9 a.m. to 3 p.m. and from 5 p.m. to 11 p.m.; other hours would have zero release. Continuous releases would occur throughout the 24-hour day. The estimates of all annual-average concentrations assumed the releases were continuous over the year.

Table G-3 lists the maximum unit release concentrations for the 11 combinations of the Yucca Mountain site-specific release periods and regulatory limit averaging times. The analysis estimated the unit concentrations and directions using the meteorological data during a single year from 1993 through 1997 (DIRS 102877-CRWMS M&O 1999, electronic addendum) that would result in the highest unit concentration. For all years, the unit release concentrations for a particular averaging time are within a factor of 2 of each other. Table G-3 lists the 24-hour averaged concentration for the 3- and 12-hour release scenarios because the activities associated with these scenarios would only release PM_{10}, which has annual and 24-hour regulatory limits. The estimated concentration at the point of exposure was calculated by multiplying the estimated source release rate (presented for each source in the following sections) by the maximum unit release concentration for that averaging period.

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Table G-3. Unit release concentrations (micrograms per cubic meter based on a release of 1 gram per second) and direction to maximally exposed individual location for 11 combinations of 4 release periods and 5 regulatory limit averaging times.[a]

	Direction from South Portal Development area	Unit release concentration	Direction from North Portal Operations Area	Unit release concentration
Continuous release – annual average concentration (1995)[b]				
	South-southeast	0.12	South-southeast	0.099
Continuous release – 24-hour average concentration (1993)				
	Southeast	1.0	West	0.95
Continuous release – 8-hour average concentration (1995)				
	Southeast	3.0	Southeast	2.5
Continuous release – 3-hour average concentration (1995)				
	West	6.1	West	6.1
Continuous release – 1-hour average concentration (1995)				
	West	18	West	18
8-hour release (8 a.m. to 4 p.m.) – 24-hour average concentration (1997)				
	West-southwest	0.19	West-northwest	0.18
8-hour release (8 a.m. to 4 p.m.) – 8-hour average concentration (1997)				
	West-southwest	0.57	West-northwest	0.52
8-hour release (8 a.m. to 4 p.m.) – 3-hour average concentration (1997)				
	West-southwest	1.5	West-northwest	1.4
8-hour release (8 a.m. to 4 p.m.) – 1-hour average concentration (1997)				
	West-northwest	3.3	West-northwest	3.3
12-hour release (9 a.m. to 3 p.m. and 5 p.m. to 11 p.m.) – 24-hour average concentration (1997)				
	West	0.95	West	0.95
3-hour release (9 a.m. to 12 p.m.) – 24-hour average concentration (1997)				
	West-northwest	0.17	West-northwest	0.17

a. Numbers are rounded to two significant figures.
b. Number in parentheses is the year from 1993 through 1997 for which meteorological data would result in the highest unit concentration.

G.1.4 CONSTRUCTION PHASE

This section describes the method used to estimate air quality impacts during the 5-year construction phase. DOE would complete the surface facilities during the construction phase, as well as sufficient excavation of the subsurface to support initial emplacement activities.

This analysis used calculations of the pollutant concentrations from various construction activities to determine air quality impacts. To calculate these impacts, estimated pollutant emission rates discussed in this section were multiplied by the unit release concentration (see Section G.1.3). This produced the pollutant concentration for comparison to regulatory limits. Short-term pollutant emission rates and concentrations were estimated using the method described in Section G.1.1.

The principal emission sources of particulates would be fugitive dust from construction activities on the surface, excavation of rock from the repository, storage of material on the excavated rock pile, and dust emissions from the concrete batch facility. The principal sources of nitrogen dioxide, sulfur dioxide, and carbon monoxide would be fuel combustion in trucks, cranes, and graders and emissions from a boiler in the South Portal Development Area. Nitrogen dioxide, sulfur dioxide, and carbon monoxide would also be emitted during maintenance of the excavated rock pile. The following sections describe these sources in more detail.

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G.1.4.1 Fugitive Dust Emissions from Surface Construction

Fugitive dust would be generated during such construction activities as earth moving and truck traffic. All surface construction activities and associated fugitive dust releases were assumed to occur during 250 working days per year with one 8-hour shift per day. The preferred method suggested by the Environmental Protection Agency would be to break the construction activities into component activities (for example, earth moving, truck traffic) and calculate the emissions for each component. However, detailed information was not available for the construction phase, so a generic, conservative approach was taken. The release rate of total suspended particulates (particulates with aerodynamic diameters of 30 micrometers or less) was estimated as 0.27 kilogram per square meter (1.2 tons per acre) per month (DIRS 101824-EPA 1995, pp. 13.2.3-1 to 13.2.3-7). This estimated emission rate for total suspended particulates was based on measurements made during the construction of apartments and shopping centers.

The amount of PM_{10} (the pollutant of interest) emitted from the construction of the Yucca Mountain Repository probably would be less than 0.27 kilogram per square meter (1.2 tons per acre) per month because many of the particulates suspended during construction would be at the larger end of the 30-micrometer range and would tend to settle rapidly (DIRS 102180-Seinfeld 1986, pp. 26 to 31). Experiments on dust suspension due to construction found that at 50 meters (160 feet) downwind of the source, a maximum of 30 percent of the remaining suspended particulates at respirable height were in the PM_{10} range (DIRS 103678-Midwest Research Institute 1988, pp. 22 to 26). Based on this factor, only 30 percent of the 0.27 kilogram per square meter per month of total suspended particulates, or 0.081 kilogram per square meter (0.36 ton per acre) per month, would be emitted as PM_{10} from construction activities. Because the default emission rate was based on continuous emissions over 30 days, the daily PM_{10} emission rate would be 0.0027 kilogram per square meter (0.012 ton per acre) per day, or 0.00011 kilogram per square meter (0.00050 ton per acre) per hour. Dust suppression activities would reduce PM_{10} emissions; however, the analysis took no credit for normal dust suppression activities.

The estimation of the annual and 24-hour average PM_{10} emission rates required an estimate of the size of the area to be disturbed along with the unit area emission rate [0.00011 kilogram per square meter (0.00050 ton per acre) per hour] times 8 hours of construction per day. The analysis estimated that 20 percent of the total disturbed land area would be actively involved in construction activities at any given time. This was based on the total disturbed area at the end of the construction period divided by the number of years construction activities would last. Table G-4 lists the total areas of disturbance at various repository operation areas. The analysis assumed that the entire land area required for excavated rock storage (for both the construction phase and operation period) would be disturbed by excavated rock storage preparation activities, although only a portion of it would be used during the construction phase. Table G-5 lists fugitive dust emissions from surface construction; Table G-6 lists estimated air quality impacts from fugitive dust as the pollutant concentration in air and as the percent of the applicable regulatory limit.

Fugitive dust from construction would produce small offsite PM_{10} concentrations. The annual and 24-hour average concentrations of PM_{10} would be as high as 1.4 percent and about 3.3 percent, respectively, of the regulatory limit for the lower-temperature repository operating mode. The differences between the operating modes would be small; the lower-temperature repository operating mode would have the larger impacts due mainly to the area required for ventilation shafts, excavated rock storage, and aging pad construction, where used.

For Modules 1 and 2, the same technique was used as for the Proposed Action, but the amount of land disturbed would be larger than for the Proposed Action because of the need for more ventilation shafts and excavated rock storage. The increase in disturbed land area would increase the estimated air quality impacts. Higher-temperature repository operating mode impacts would be 1.2 percent (annual) and

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2.8 percent (24-hour) of the regulatory limit. Lower-temperature repository operating mode impacts would be 1.2 to 1.7 percent (annual) and 2.9 to 4 percent (24-hour) of the regulatory limit.

Table G-4. Land area (square kilometers)[a] disturbed during the construction phase.[b]

Operations area	Operating mode: Higher-temperature	Operating mode: Lower-temperature
North Portal and roads	0.62	0.62
South Portal	0.15	0.15
Ventilation shafts and access roads	0.84	1 - 1.4
Total excavated rock storage	0.87	0.87 - 1.5
Landfill	0.04	0.04 - 0.061
Solar power generating station	0.22	0.22
Concrete batch plant	0.061	0.061
Concrete pads for aging	NA[c]	0 or 0.47[d]
Totals[e]	***2.8***	***3 - 4.5***
Area disturbed per year	0.55	0.6 - 0.83

a. To convert square kilometers to acres, multiply by 247.1.
b. Sources: DIRS 152010-CRWMS M&O (2000, p. 52); DIRS 150941-CRWMS M&O (2000, pp. 4-9 and 6-27); DIRS 150941-CRWMS M&O (2000, p. 1); DIRS 155515-Williams (2001, Part 1, pp. 27 and 29; Part 2, p. 18); DIRS 155516-Williams (2001, Item 1.5); DIRS 153882-Griffith (2001, p. 8).
c. NA = not applicable.
d. Applicable only for aging.
e. Numbers are rounded to two significant figures; therefore, totals might differ from sums of values.

Table G-5. Fugitive dust releases from surface construction (PM_{10}).[a]

Operating mode	Period	Pollutant emission (kilograms)[b]	Emission rate (grams per second)[c]
Higher-temperature	Annual	120,000	3.9
	24-hour	490	17[d]
Lower-temperature[e]	Annual	130,000 - 190,000	4.2 - 5.9
	24-hour	530 - 740	18 - 26[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on an 8-hour release period.
e. Range of values for lower-temperature operating mode.

Table G-6. Estimated fugitive dust air quality impacts (micrograms per cubic meter) from surface construction (PM_{10}).[a]

Operating mode	Period	Maximum concentration	Regulatory limit	Percent of limit
Higher-temperature	Annual	0.47	50	0.95
	24-hour	3.3	150	2.2
Lower-temperature	Annual	0.51 - 0.71	50	1 - 1.4
	24-hour	3.5 - 4.9	150	2.4 - 3.3

a. Numbers are rounded to two significant figures.

G.1.4.2 Fugitive Dust from Subsurface Excavation

Fugitive dust would be released during the excavation of rock from the repository. Subsurface excavation activities would take place 250 days per year in three 8-hour shifts per day. Excavation would generate dust in the tunnels, and some of the dust would be emitted to the surface atmosphere through the ventilation system. DOE estimated the amount of dust that would be emitted by the ventilation system by using engineering judgment and best available information (DIRS 104494-CRWMS M&O 1998, p. 37).

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Table G-7 lists the release rates of PM_{10} for excavation activities. Table G-8 lists estimated air quality impacts from fugitive dust as pollutant concentration in air and percentage of regulatory limit.

Table G-7. Fugitive dust releases from excavation activities (PM_{10}).[a]

Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
Annual	920	0.029
24-hour	3.7	0.043[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a 24-hour release period.

Table G-8. Fugitive dust (PM_{10}) and cristobalite air quality impacts (micrograms per cubic meter) from excavation activities.

Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
PM_{10}			
Annual	0.0035	50	0.0070
24-hour	0.044	150	0.029
Cristobalite			
Annual	0.0010	10[b]	0.010

a. Numbers are rounded to two significant figures.
b. This value is a benchmark; there is no regulatory limit for cristobalite. See Section G.1.

Fugitive dust emissions from excavation operations would produce small offsite PM_{10} concentrations. Both annual and 24-hour average concentrations of PM_{10} would be much less than 1 percent of the regulatory standards. The highest estimated annual and 24-hour excavation rates, and hence the highest estimated fugitive dust concentrations, would be the same for all operating modes.

Dust generated during excavation would contain cristobalite, a naturally occurring form of crystalline silica discussed in Section G.1. The analysis estimated the amount of cristobalite released by multiplying the amount of dust released annually (shown in Table G-7) by the percentage of cristobalite in the parent rock (28 percent). Table G-8 also lists the potential air quality impacts for releases of cristobalite from excavation of the repository. Because there are no public exposure limits for cristobalite, the annual average concentration was compared to a derived benchmark level for the prevention of silicosis, as discussed in Section G.1. The offsite cristobalite concentration would be about 0.01 percent of this benchmark.

The air quality impacts from fugitive dust emissions from excavation operations during the construction phase would be the same for Modules 1 and 2 as for the Proposed Action.

G.1.4.3 Fugitive Dust from Excavated Rock Pile

The disposal and storage of excavated rock on the surface excavated rock pile would generate fugitive dust. Dust would be released during the unloading of the excavated rock and subsequent smoothing of the excavated rock pile, as well as by wind erosion of the material. DOE used the total suspended particulate emission for active storage piles to estimate fugitive dust emission (DIRS 103676-Cowherd, Muleski, and Kinsey 1988, pp. 4-17 to 4-37). The equation is:

$$E = 1.9 \times (s \div 1.5) \times [(365 - p) \div 235] \times (f \div 15)$$

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where E = total suspended particulate emission factor (kilogram per day per hectare [1 hectare = 0.01 square kilometer = 2.5 acres])
s = silt content of aggregate (percent)
p = number of days per year with 0.25 millimeter or more of precipitation
f = percentage of time wind speed exceeds 5.4 meters per second (12 miles per hour) at pile height

For this analysis, *s* is equal to 4 percent, a conservative default value based on the average silt content of limestone quarrying material (DIRS 101824-EPA 1995, p. 13.2.4-2), *p* is 37.75 (DIRS 104497-Fosmire 1999, all) and *f* is 16.5 (calculated from meteorological data used in the Industrial Source Complex model). Thus, *E* is equal to 7.8 kilograms of total particulates per day per hectare (6.9 pounds per day per acre). Only about 50 percent of the total particulates would be PM_{10} (DIRS 103676-Cowherd, Muleski, and Kinsey 1988, pp. 4-17 to 4-37); therefore, the emission rate for PM_{10} would be 3.9 kilograms per day per hectare (3.5 pounds per day per acre).

The analysis estimated fugitive dust from disposal and storage using the size of the area actively involved in storage and maintenance. Only a portion of the excavated rock pile would be actively disturbed by the unloading of excavated rock and the subsequent contouring of the pile, and only that portion would be an active source of fugitive dust. The analysis assumed that the rest of the excavated rock pile would be stabilized by either natural processes or DOE stabilization measures and would release small amounts of dust. Dust suppression measures applied to the active area of the pile would reduce the calculated releases.

DOE based its estimate of the size of the active portion of the excavated rock pile on the amount of material it would store there each year (see Table G-9). The volume of rock placed on the excavated rock pile from excavation activities during the construction phase (DIRS 150941-CRWMS M&O 2000, p. 6-6; DIRS 155515-Williams 2001, Part 2, p. 12; Part 2, p. 10) was divided by the height of the storage pile. The average height of the excavated rock pile would be about 6 meters (20 feet) for the higher-temperature operating mode and about 8 meters high (26 feet) for the lower-temperature operating mode. The pile heights for Inventory Modules 1 and 2 would also be 6 meters for the higher-temperature operating mode and 8 to 9 meters for the lower-temperature operating mode. The active area of the excavated rock pile was estimated using the total area of the rock pile at the end of the construction phase divided by five years of construction, with this quantity then multiplied by two (DIRS 104505-Fosmire 1999, all).

Table G-9. Characteristics of excavated rock pile during the construction phase.[a,b]

Operating mode	Rock pile area (square kilometers)[c]	Pile height (meters)	Average annual active area (square kilometers)
Higher-temperature	0.27	6	0.11
Lower-temperature	0.26 - 0.28	8	0.10 - 0.11

a. Numbers are rounded to two significant figures.
b. The construction phase would last 5 years. Subsurface excavation and rock pile activities would continue during the operation and monitoring phase (see Section G.1.5).
c. To convert square kilometers to square miles, multiply by 0.3861.

Table G-10 lists the fugitive dust release rate from disposal and storage of the excavated rock pile for the operating modes. Table G-11 lists the air quality impacts from fugitive dust as pollutant concentration and percent of regulatory limit.

Fugitive dust emissions from the excavated rock pile during the construction phase would produce small offsite PM_{10} concentrations. Both the annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards.

Table G-10. Fugitive dust released from the excavated rock pile during the construction phase (PM_{10}).[a]

Operating mode	Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
Higher-temperature	Annual	16,000	0.49
	24-hour	42	0.49[d]
Lower-temperature	Annual	15,000 - 16,000	0.47 - 0.51
	24-hour	41 - 44	0.47 - 0.51[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a continuous release.

Table G-11 also lists potential air quality impacts for releases of cristobalite. The methods used were the same as those described in Section G.1.4.2 for the construction phase, where cristobalite was assumed to be 28 percent of the fugitive dust released, based on its percentage in parent rock. The land withdrawal area boundary cristobalite concentration would be small, about 0.21 percent or less of the benchmark level discussed in Section G.1.

Table G-11. Fugitive dust (PM_{10}) and cristobalite air quality impacts (micrograms per cubic meter) from the excavated rock pile during the construction phase.

Operating mode	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
PM_{10}				
Higher-temperature	Annual	0.059	50	0.12
	24-hour	0.50	150	0.34
Lower-temperature	Annual	0.057 - 0.062	50	0.11 - 0.12
	24-hour	0.48 - 0.53	150	0.32 - 0.35
Cristobalite				
Higher-temperature	Annual	0.017	10[c]	0.17
Lower-temperature	Annual	0.016 - 0.017	10[c]	0.16 - 0.17

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.
c. This value is a benchmark; there are no regulatory limits for cristobalite other than worker exposure limits. See Section G.1.

For Modules 1 and 2, the volume of rock excavated during the construction phase would be the same as that excavated for the Proposed Action (DIRS 152010-CRWMS M&O 2000, p. 6-6; DIRS 155515-Williams 2001, Part 1, p. 12; and Part 2, p. 10). The estimated air quality impacts would be identical for the Proposed Action and for Modules 1 and 2.

G.1.4.4 Fugitive Dust from Concrete Batch Facility

The concrete batch facility for the fabrication and curing of tunnel inverts and tunnel liners would emit dust. This facility would run 3 hours a day and would produce 100 cubic meters (130 cubic yards) of concrete per hour of operation (DIRS 104523-CRWMS M&O 1999, pp. 4-4 and 4-5). It would operate 250 days per year. Table G-12 lists emission factor estimates for the concrete batch facility (DIRS 101824-EPA 1995, pp. 11.12-1 to 11.12-5). About 0.76 cubic meter (1 cubic yard) of typical concrete weighs 1,800 kilograms (4,000 pounds) (DIRS 101824-EPA 1995, p. 11.12-3). The size of the aggregate storage pile for the concrete batch facility would be 800 square meters (0.2 acre) (DIRS 104523-CRWMS M&O 1999, pp. 4-4 and 4-5).

Table G-12. Dust release rates for the concrete batch facility (kilograms per 1,000 kilograms of concrete).[a,b]

Source/activity	Emission rate
Sand and aggregate transfer to elevated bin	0.014
Cement unloading to elevated storage silo	0.13
Weight hopper loading	0.01
Mixer loading	0.02
Wind erosion from aggregate storage	3.9 kilograms per hectare[c] per day

a. Source: DIRS 101824-EPA (1995, p. 11.12-3).
b. To convert kilograms to pounds, multiply by 2.2046.
c. 3.9 kilograms per hectare = about 21 pounds per acre.

Table G-13 lists the dust release rates of the concrete batch facility. Table G-14 lists estimated potential air quality impacts as the estimated pollutant concentration and percent of regulatory limit.

Table G-13. Dust release rates for the concrete batch facility during the construction phase (PM_{10}).[a]

Operating mode	Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
Higher-temperature	Annual	36,000	1.1
	24-hour	140	13[d]
Lower-temperature	Annual	36,000 - 46,000	1.1 - 1.5
	24-hour	140 - 180	13 - 17[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a 3.5- to 4.5- hour release period.

Table G-14. Particulate matter (PM_{10}) air quality impacts (micrograms per cubic meter) from the concrete batch facility during the construction phase.

Operating mode	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Higher-temperature	Annual	0.11	50	0.23
	24-hour	2.2	150	1.5
Lower-temperature	Annual	0.11 - 0.15	50	0.23 - 0.29
	24-hour	2.2 - 2.8	150	1.5 - 1.9

a. Numbers are rounded to two significant figures.

Dust emissions from the concrete batch facility during the operation and monitoring phase would produce small offsite PM_{10} concentrations. The annual and 24-hour averaged concentrations of PM_{10} would be less than 1 percent and about 2 percent of the regulatory standards, respectively.

For Modules 1 and 2, the air quality impacts from the concrete batch facility during the construction phase would be the same as for the Proposed Action.

G.1.4.5 Exhaust Emissions from Construction Equipment

Diesel- and gasoline-powered equipment would emit all four criteria pollutants during the construction phase. DIRS 103679-EPA (1991, pp. II-7-1 to II-7-7) provided pollutant emission rate estimates for heavy-duty equipment. This analysis assumed construction equipment would emit the average of the EPA reference emission rates. Emission rates from construction equipment could decrease significantly in the future. Legislation signed in early 2001 would create year 2007 emission standards that would reduce diesel vehicle emissions of particulate matter (90-percent reduction), nitrogen dioxide (95-percent reduction), and sulfur dioxide (97-percent reduction) (DIRS 155098-EPA 2000, all). Table G-15 lists the current emission rates for this equipment.

Table G-15. Pollutant emission rates (kilograms[a] per 1,000 liters[b] of fuel) for construction equipment.[c]

	Estimated emission	
Pollutant	Diesel	Gasoline
arbon monoxide	15	450
itrogen dioxide	39	13
M_{10}	3.5	0.86
ulfur dioxide	3.7	0.63

a. To convert kilograms to pounds, multiply by 2.2046.
b. To convert liters to gallons, multiply by 0.26418.
c. Source: Average of rates from DIRS 103679-EPA (1991, pp. II-7-1 to II-7-7).

Table G-16 lists the estimated average amount of fuel consumed per year during the construction phase. The fuel for the South Portal Development Area would include fuel consumed during maintenance of the excavated rock pile.

Table G-16. Amount of fuel consumed per year during the construction phase (liters).[a,b]

	South Portal Development Area		North Portal Operations Area[d]
Operating mode	Diesel	Gasoline	Diesel
Higher-temperature	300,000[c]	20,000[c]	770,000
Lower-temperature	430,000 - 460,000[e,f]	20,000[e]	770,000

a. To convert liters to gallons, multiply by 0.26418.
b. Numbers are rounded to two significant figures.
c. Source: Based on total fuel use from DIRS 150941-CRWMS M&O (2000, p. 6-3).
d. Source: Based on total fuel use from DIRS 152010-CRWMS M&O (2000, p. 48).
e. Source: Based on total fuel use from DIRS 155515-Williams (2001, Part 1, p. 9; and Part 2, p.7).
f. Source: Aging pad contribution derived from DIRS 152010-CRWMS M&O (2000, Table I-2).

Table G-17 lists pollutant releases from construction equipment for each operating mode. The emission rate for the annual concentration was calculated from the total fuel consumed, assuming the same amount of fuel would be consumed each year.

Table G-18 lists the impacts on air quality from construction equipment emission by operating mode as the maximum pollutant concentration in air and the percentage of the regulatory limit. Emissions from surface equipment during the construction phase would produce small offsite (outside the land withdrawal area) criteria pollutant concentrations. All concentrations would be less than 1 percent of the regulatory standards. The impacts from fuel use under Inventory Modules 1 and 2 would be the same as those under the Proposed Action because fuel use would be the same during construction.

G.1.4.6 Exhaust from Boiler

A proposed boiler in the North Portal Operations Area would emit the four criteria pollutants. The boiler would use diesel fuel and provide steam and hot water for the heating, ventilation, and air conditioning system. DOE assumed this boiler to be the same size as the boiler that would operate during the operation and monitoring phase (DIRS 152010-CRWMS M&O 2000, Table 6-2, p. 52). Table G-19 lists the annual emission rates of the boiler. To estimate the short-term (24 hours or less) emission rate, the analysis assumed the boiler would run 250 days (6,000 hours) per year. Given the annual boiler emissions, this was a conservative assumption because continuous operation 365 days (8,760 hours) per

Table G-17. Pollutant release rates from surface equipment during the construction phase.[a]

Pollutant	Period	Mass of pollutant per averaging period (kilograms)[b]		Emission rate[c] (grams per second)[d]	
		South	North	South	North
Higher-temperature operating mode					
Nitrogen dioxide	Annual	12,000	30,000	0.38	0.95
Sulfur dioxide	Annual	1,100	2,900	0.036	0.090
	24-hour	4.5	12	0.16	0.40
	3-hour	1.7	4.3	0.16	0.40
Carbon monoxide	8-hour	54	47	1.9	1.6
	1-hour	6.7	5.8	1.9	1.6
PM_{10}	Annual	1,100	2,700	0.034	0.085
	24-hour	4.2	11	0.15	0.37
Lower-temperature operating mode					
Nitrogen dioxide	Annual	17,000 - 18,000	30,000	0.55 - 0.58	0.95
Sulfur dioxide	Annual	1,600 - 1,700	2,900	0.051 - 0.055	0.091
	24-hour	6.5 - 6.9	12	0.22 - 0.24	0.40
	3-hour	2.4 - 2.6	4.3	0.22 - 0.24	0.40
Carbon monoxide	8-hour	62 - 63	47	2.1 - 2.2	1.6
	1-hour	7.7 - 7.9	5.8	2.1 - 2.2	1.6
PM_{10}	Annual	1,500 - 1,600	2,700	0.048 - 0.051	0.085
	24-hour	6.1 - 6.5	11	0.040 - 0.043	0.37

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release for averaging periods 24 hours or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-18. Air quality impacts from construction equipment during the construction phase (micrograms per cubic meter).[a]

Pollutant	Period	Maximum concentration	Regulatory limit[b]	Percent of regulatory limit
Higher-temperature operating mode				
Nitrogen dioxide	Annual	0.17	100	0.17
Sulfur dioxide	Annual	0.016	80	0.021
	24-hour	0.11	365	0.031
	3-hour	0.9	1,300	0.069
Carbon monoxide	8-hour	2.1	10,000	0.02
	1-hour	12	40,000	0.03
PM_{10}	Annual	0.015	50	0.03
	24-hour	0.1	150	0.07
Lower-temperature operating mode				
Nitrogen dioxide	Annual	0.18 - 0.19	100	0.18 - 0.19
Sulfur dioxide	Annual	0.017 - 0.018	80	0.022 - 0.023
	24-hour	0.12	365	0.033
	3-hour	0.95 - 0.98	1,300	0.073 - 0.075
Carbon monoxide	8-hour	2.1 - 2.2	10,000	0.021
	1-hour	12 - 13	40,000	0.031 - 0.032
PM_{10}	Annual	0.016	50	0.032 - 0.033
	24-hour	0.11	150	0.074 - 0.076

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Table G-19. Annual pollutant release rates (kilograms per year)[a] for the North Portal Operations Area boiler.[b,c]

Pollutant	Annual emission rate
Nitrogen dioxide	81,000
Sulfur dioxide	28,000
Carbon monoxide	20,000
PM_{10}	7,800

a. To convert kilograms to tons, multiply by 0.0011023.
b. Source: DIRS 152010-CRWMS M&O (2000, p. 52).
c. Numbers are rounded to two significant figures.

year would result in lower daily emissions. This assumption considered periods when the boiler would not be operating. The actual period of boiler operation is not known. In addition, specific information on the boiler stack height and exhaust air temperature (which would affect plume rise) has not been developed. These releases were assumed to be from ground level, which also tends to overestimate actual concentrations. Table G-20 lists releases of criteria pollutants by the boiler. Table G-21 lists estimated potential air quality impacts as pollutant concentrations in air and percent of regulatory limit.

Table G-20. Pollutant release rates from the boiler during the construction phase.[a,b]

Pollutant	Period	Mass of pollutant (kilograms)[c] per averaging time	Emission rate[d] (grams per second)[e]
Nitrogen dioxide	Annual	81,000	2.6
Sulfur dioxide	Annual	28,000	0.87
	24-hour	110	1.3
	3-hour	14	1.3
Carbon monoxide	8-hour	27	0.94
	1-hour	3.4	0.94
PM_{10}	Annual	7,800	0.25
	24-hour	32	0.36

a. Numbers are rounded to two significant figures.
b. These release rates also apply for the operation and monitoring phase (see Section G.1.5.6).
c. To convert kilograms to pounds, multiply by 2.2046.
d. Based on an 8-hour release for averaging periods of 24 hours or less.
e. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-21. Air quality impacts from boiler pollutant releases from the North Portal Operations Area during the construction phase (micrograms per cubic meter of pollutant).[a]

Pollutant	Period	Maximum concentration[b]	Regulatory limit[c]	Percent of regulatory limit[b]
Nitrogen dioxide	Annual	0.25	100	0.25
Sulfur dioxide	Annual	0.086	80	0.11
	24-hour	1.2	365	0.33
	3-hour	7.7	1,300	0.59
Carbon monoxide	8-hour	2.3	10,000	0.023
	1-hour	17	40,000	0.043
PM_{10}	Annual	0.025	50	0.050
	24-hour	0.34	150	0.23

a. These release rates also apply for the operation and monitoring phase (see Section G.1.5.6).
b. Numbers are rounded to two significant figures.
c. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Emissions from the boiler during the construction phase would produce small offsite (outside the land withdrawal area) criteria pollutant concentrations. All concentrations would be less than 1 percent of the regulatory standards.

There would be no differences among repository operating modes. The air quality impacts from the boiler during the construction phase under Inventory Models 1 and 2 would be the same as those for the Proposed Action.

G.1.5 OPERATION AND MONITORING PHASE

This section describes the method DOE used to estimate air quality impacts during the operation and monitoring phase. As for the construction phase, impacts were evaluated for each year or for shorter time periods. Activities during this phase would include the continued development of the subsurface facilities, which would last 22 years for all operating modes. Emplacement activities in the surface and subsurface facilities would last 24 years, the first 22 years concurrent with continued development activities. Monitoring and maintenance would begin after the end of emplacement operations. For purposes of analysis, workers would use the following schedule for activities during the operation and monitoring phase: three 8-hour shifts a day, 5 days a week, 50 weeks a year. The maintenance of the excavated rock pile would occur in one 8-hour shift a day, 5 days a week, 50 weeks a year.

For Modules 1 and 2, the continued development of the subsurface facilities would last 36 years. Emplacement activities in the surface and subsurface facilities would continue concurrently with development operations but last an additional 2 years (38 years total).

The analysis estimated air quality impacts by calculating pollutant concentrations from various operation and monitoring activities. Emission rates were developed for each activity that would result in pollutant releases. The emission rates were multiplied by the unit release concentrations (see Section G.1.3) to calculate the pollutant concentration for comparison to the various regulatory limits.

The principal emission sources of particulates would be dust emissions from concrete batch facility operations and fugitive dust emissions from excavation and storage on the excavated rock pile. In addition, fugitive dust from earthmoving activities would be emitted during final aging pad construction. Fuel combustion from maintenance of the excavated rock pile and emissions from the North Portal boiler would be principal sources of nitrogen dioxide, sulfur dioxide, and carbon monoxide. The following sections describe these sources in more detail.

G.1.5.1 Fugitive Dust from Surface Construction

For the lower-temperature repository operating mode with aging, fugitive dust would be emitted when the remaining aging pads were constructed during the operation and monitoring phase. If the pads were constructed at a rate of 0.12 square kilometer (30 acres) per year, as in the construction phase (see Section G.1.4.1), the estimated maximum PM_{10} air concentrations would be 0.05 percent and 0.12 percent of the annual and daily regulatory limits, respectively, for PM_{10}.

G.1.5.2 Fugitive Dust from Concrete Batch Facility

The concrete batch facility for the fabrication and curing of tunnel inverts and liners, remaining surface facility construction (solar power and spent nuclear fuel aging facilities), and dry cask construction would emit dust. Batch plant daily run times would be shorter than those during the construction phase, ranging from 0.5 to 2.0 hours. The dust release rate and potential air quality impacts are listed in Tables G-22 and G-23, respectively.

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Table G-22. Dust release rates for the concrete batch facility during the operation and monitoring phase (PM_{10})[a]

Operating Mode	Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
Higher-temperature	Annual	5,200	0.12
	24-hour	21	1.9[d]
Lower-temperature	Annual	10,000 - 21,000	0.33 - 0.65
	24-hour	41 - 83	3.8 - 7.6[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Higher-temperature based on 0.5-hour, lower-temperature on 1-to-2 hour release period.

Table G-23. Particulate matter (PM_{10}) air quality impacts (micrograms per cubic meter) from the concrete batch facility during the operation and monitoring phase.

Operating Mode	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Higher-temperature	Annual	0.02	50	0.040
	24-hour	0.32	150	0.21
Lower-temperature	Annual	0.040 - 0.079	50	0.079 - 0.16
	24-hour	0.63 - 1.3	150	0.42 - 0.84

a. Numbers are rounded to two significant figures.

G.1.5.3 Fugitive Dust from Subsurface Excavation

The excavation of rock from the repository would generate fugitive dust in the drifts. Some of the dust would reach the external atmosphere through the repository ventilation system. Fugitive dust emission rates from excavation during operations would be the same as those during the construction phase. Thus, the fugitive dust release rate and potential air quality impacts for excavation of rock would be the same as those listed in Tables G-7 and G-8. Air quality impacts from cristobalite released during excavation of the repository would be the same as those listed in Table G-8.

G.1.5.4 Fugitive Dust from Excavated Rock Pile

The disposal and storage of excavated rock on the excavated rock pile would release fugitive dust. The analysis used the same method to estimate fugitive dust releases from the excavated rock pile during operations that it used for the construction phase (See Section G.1.4.3). Table G-24 lists the areas of the active portion of the excavated rock pile for each operating mode. The total land area used for storage and the active portion of the excavated rock pile was based on the amount of rock that would be stored during operations (DIRS 150941-CRWMS M&O 2000, p. 6-11; DIRS 155515-Williams 2001, Part 1, p. 17; and Part 2, p. 15). Sections G.1.4.1 and G.1.4.3 compare the excavated rock pile areas.

Table G-24. Characteristics of excavated rock pile area during subsurface excavation activities of the operation and monitoring phase.[a]

Operating mode	Rock pile area (square kilometers)[b]	Pile height (meters)	Annual average active area (square kilometers)
Higher-temperature	0.87	6	0.055
Lower-temperature	0.86 - 1.4	8	0.053 - 0.10

a. Numbers are rounded to two significant figures.
b. To convert square kilometers to acres, multiply by 247.1.

While the land area used for storage of excavated rock during the operation and monitoring phase would be nearly twice as large as that used during the construction phase for the higher-temperature repository operating mode, the active area per year would be about half of that for construction due to the larger number of years over which continued development would occur (22 years compared to 5 years). The land area used during the operation and monitoring phase would be 3 to 5 times that used during the construction phase. The stored volume of excavated rock would be larger during the operation and monitoring phase than during the construction phase. Table G-25 lists fugitive dust releases from the excavated rock pile; Table G-26 lists potential air quality impacts as the pollutant concentration and percent of the regulatory limit.

Table G-25. Fugitive dust release rate from the excavated rock pile during the operation and monitoring phase (PM_{10}).[a]

Operating mode	Period	Emissions (kilograms)[b]	Emission rate[c] (grams per second)[d]
Higher-temperature	Annual	7,800	0.25
	24-hour	21	0.25
Lower-temperature	Annual	7,600 - 15,000	0.24 - 0.46
	24-hour	21 - 40	0.24 - 0.46

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on a continuous release.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-26. Fugitive dust (PM_{10}) and cristobalite air quality impacts from the excavated rock pile during the operation and monitoring phase (micrograms per cubic meter).

Operating mode	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
PM_{10}				
Higher-temperature	Annual	0.03	50	0.06
	24-hour	0.25	150	0.17
Lower-temperature	Annual	0.029 - 0.056	50	0.058 - 0.11
	24-hour	0.25 - 0.47	150	0.16 - 0.32
Cristobalite				
Higher-temperature	Annual	0.0084	10[c]	0.084
Lower-temperature	Annual	0.0081 - 0.016	10[c]	0.081 - 0.16

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.
c. This value is a benchmark; there is no regulatory limit for cristobalite. See Section G.1.

Fugitive dust emissions from the excavated rock pile during the operation and monitoring phase would produce very small offsite (outside the land withdrawal area) PM_{10} concentrations. Both annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards for all operating modes.

Table G-26 also lists potential air quality impacts for releases of cristobalite. The methods used were the same as those described in Section G.1.4.2 for the construction phase, where cristobalite was assumed to be 28 percent of the fugitive dust released, based on its percentage in parent rock. The site boundary cristobalite concentration would be small, about 0.1 percent of the benchmark level discussed in Section G.1.

The Module 1 and 2 analysis used the same technique as for the Proposed Action. The stored rock pile area for Inventory Modules 1 and 2 would be approximately twice the size of the piles for the Proposed

Action operating modes, but the excavation period would be extended as well. The estimated air quality impacts would be only 1.2 times larger for Modules 1 and 2.

G.1.5.5 Exhaust from Surface Equipment

Surface equipment would emit the four criteria pollutants during excavated rock pile maintenance, surface operation, and any remaining surface facility construction. The analysis used the same method to determine air quality impacts for surface equipment during operations used for the construction phase (see Section G.1.4.5). Table G-15 lists the pollutant release rates of the equipment. Table G-27 lists the average amount of fuel consumed each year during the operation and monitoring phase at the South Portal Development Area.

Table G-27. Annual amount of fuel (liters)[a] consumed during the operation and monitoring phase.[b]

Operating mode	Diesel	Gasoline
Higher-temperature[c]	170,000	4,500
Lower-temperature[d]	210,000 - 400,000[e]	4,500

a. To convert liters to gallons, multiply by 0.26418.
b. Numbers are rounded to two significant figures.
c. Source: Based on total fuel use from DIRS 150941-CRWMS M&O (2000, pp. 6-8 and 6-13).
d. Source: DIRS 155515-Williams (2001, Part 1, pp. 14 and 18; Part 2, pp. 12 and 16).
e. Source: Derived using DIRS 152010-CRWMS M&O (2000, Table I-2).

Table G-28 lists pollutant release rates for surface equipment during operations activities of the operation and monitoring phase. Monitoring activity emissions would be much smaller. Table G-29 lists potential air quality impacts.

Table G-28. Pollutant release rates from surface equipment during the operation and monitoring phase.[a]

Pollutant	Period	Mass of pollutant per averaging time (kilograms)[b]	Emission rate[c] (grams per second)[d]
Higher-temperature operating mode			
Nitrogen dioxide	Annual	13,000	0.41
Sulfur dioxide	Annual	1,200	0.039
	24-hour	4.9	0.17
	3-hour	1.8	0.17
Carbon monoxide	8-hour	28	0.97
	1-hour	3.5	0.97
PM_{10}	Annual	1,100	0.036
	24-hour	4.6	0.16
Lower-temperature operating mode			
Nitrogen dioxide	Annual	14,000 - 20,000	0.46 - 0.62
Sulfur dioxide	Annual	1,400 - 1,900	0.044 - 0.059
	24-hour	5.5 - 7.5	0.19 - 0.26
	3-hour	2.1 - 2.8	0.19 - 0.26
Carbon monoxide	8-hour	30 - 38	1 - 1.3
	1-hour	3.8 - 4.8	1 - 1.3
PM_{10}	Annual	1,300 - 1,700	0.041 - 0.055
	24-hour	5.1 - 7	0.18 - 0.24

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release for averaging periods of 24 hours or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-29. Air quality impacts from surface equipment during the operation and monitoring phase (micrograms per cubic meter of pollutant).

Pollutant	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Higher-temperature operating mode				
Nitrogen dioxide	Annual	0.052	100	0.052
Sulfur dioxide	Annual	0.0049	80	0.0062
	24-hour	0.034	365	0.0093
	3-hour	0.27	1,300	0.021
Carbon monoxide	8-hour	0.57	10,000	0.0056
	1-hour	3.3	40,000	0.0083
PM_{10}	Annual	0.0046	50	0.0091
	24-hour	0.032	150	0.021
Lower-temperature operating mode				
Nitrogen dioxide	Annual	0.058 - 0.078	100	0.058 - 0.078
Sulfur dioxide	Annual	0.0055 - 0.0073	80	0.0070 - 0.0094
	24-hour	0.038 - 0.051	365	0.01 - 0.014
	3-hour	0.3 - 0.41	1,300	0.023 - 0.031
Carbon monoxide	8-hour	0.62 - 0.78	10,000	0.006 - 0.0076
	1-hour	3.6 - 4.5	40,000	0.009 - 0.011
PM_{10}	Annual	0.0051 - 0.0069	50	0.01 - 0.014
	24-hour	0.035 - 0.047	150	0.024 - 0.032

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Emissions from surface equipment during operation and monitoring would produce very small concentrations of offsite (outside the land withdrawal area) criteria pollutants. All estimated concentrations would be less than 1 percent of the regulatory standards.

Modules 1 and 2 would use fuel at a slightly higher rate than that for the Proposed Action at the South Portal Development Area, but at a slightly lower rate at the North Portal Operations Area. The resulting impact under Modules 1 and 2 would be the same; all estimated concentrations would be less than 1 percent of the regulatory standard.

G.1.5.6 Exhaust from Boiler

A boiler in the North Portal Operations Area would emit the four criteria pollutants. The annual emission rates are listed in Table G-19. There would be small variations in the boiler emissions for the transportation and waste packaging options because of different operational requirements. The emissions listed in Table G-19 are for the combination of legal-weight truck transport and uncanistered waste scenario, which would require the largest boiler because a larger Waste Handling Building would be required (DIRS 152010-CRWMS M&O 2000, p. 52). (The analysis assumed that identical boilers would operate under all operating modes and that the boiler would run 250 days (6,000 hours) per year.) Given an annual emission rate, this was a conservative assumption because continuous operation 365 days (8,760 hours) per year would result in lower daily emissions. This assumption considered periods when the boiler would not be operating. The actual period of boiler operation is not known. Pollutant release rates during the operation and monitoring phase would be the same as those listed in Table G-20. Table G-21 lists estimated potential air quality impacts as pollutant concentrations in air and percent of regulatory limit. Emissions from the boiler during the operation and monitoring phase would produce small offsite criteria pollutant concentrations. All concentrations would be less than 1 percent of the regulatory standards.

The estimated air quality impacts from boilers for Inventory Modules 1 and 2 during the operation and monitoring phase would be the same as those for the Proposed Action.

G.1.6 CLOSURE PHASE

This section describes the method used to estimate air quality impacts during the closure phase at the proposed repository. The closure phase is defined by the length of the subsurface closure activities, which would be directed from the South Portal Development Area. Subsurface closure for the higher-temperature operating mode of the Proposed Action would last 10 years, while subsurface closure for the lower-temperature operating mode would range from 11 to 17 years. Surface facility closure at the North Portal Operations Area would last 6 years for all operating modes. Closure of any aging pads that might be present under the lower-temperature operating mode was assumed to take place after surface facility closure was completed. Closure for Inventory Modules 1 and 2 would have a longer subsurface closure period, lasting 12 years for the higher-temperature operating mode and from 16 to 23 years for the lower-temperature operating mode. Surface facility closure for Inventory Modules 1 and 2 would be the same as for the Proposed Action. The work schedule would be one 8-hour shift per day, 5 days a week, 50 weeks a year.

Air quality impacts were estimated by calculating pollutant concentrations from various closure activities. Emission rates were developed for each activity that would result in releases of pollutants. These pollutant emission rates were then multiplied by the unit release concentration (see Section G.1.3) to calculate the pollutant concentration for comparison to the various regulatory limits.

The sources of particulates would be emissions from the backfill plant and the concrete batch facility and fugitive dust from closure activities on the surface and the reclamation of material from the excavated rock pile for backfill. The principal source of nitrogen dioxide, sulfur dioxide, and carbon monoxide during closure would be fuel combustion. The following sections describe these sources in more detail.

G.1.6.1 Dust from Backfill Plant

The Closure Backfill Preparation Plant would process (separate, crush, screen, and wash) rock from the excavated rock pile for use as backfill for the underground access openings (DIRS 104523-CRWMS M&O 1999, pp. 4-77 and 4-78). The facility would have the capacity to handle 91 metric tons (100 tons) an hour (DIRS 104523-CRWMS M&O 1999, pp. 4-77 and 4-78). For purposes of analysis, the backfill plant would run 6 hours a shift, 2 shifts a day, 5 days a week, 50 weeks a year during the closure phase.

The plant was assumed to have emissions similar to a crushed-stone processing plant. Table G-30 lists the emission rates for various activities associated with a crushed stone processing plant (DIRS 101824-EPA 1995, pp. 11.19.2-1 to 11.19.2-8). Table G-31 lists estimated pollutant release rates for the backfill plant. Table G-32 lists potential air quality impacts as pollutant concentrations in air and percent of regulatory limit.

Table G-30. Emission rates from a crushed stone processing plant.[a,b]

Source/activity	Emission rate (kilogram[c] per 1,000 kilograms of material processed)
Dump to conveyor or truck	0.00005
Screening	0.0076
Crusher	0.0012
Fine screening	0.036

a. Source: DIRS 101824-EPA (1995, pp. 11.19.2-1 to 11.19.2-8).
b. Numbers are rounded to two significant figures.
c. To convert kilograms to pounds, multiply by 2.2046.

Table G-31. Dust release rates from the backfill plant (PM_{10}).[a]

Period	Emission (kilograms)[b]	Emission rate (grams per second)[c]
Annual	12,000 per year	0.39
24-hour	49 per day	1.1[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a 12-hour release period.

Table G-32. Particulate matter (PM_{10}) air quality impacts from backfill plant (micrograms per cubic meter).

Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Annual	0.047	50	0.093
24-hour	1.1	150	0.71

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Dust emissions from the backfill plant would produce small PM_{10} concentrations. Both annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards for all operating modes.

For Modules 1 and 2, the estimated air quality impacts for the backfill plant would be the same as those for the Proposed Action.

G.1.6.2 Fugitive Dust from Concrete Batch Facility

A concrete batch facility for the fabrication of seals would be similar to the facility that would operate during the construction and operation and monitoring phases (see Sections G.1.4.4 and G.1.5.2). The only difference would be that it would run only ten 3-hour shifts a year per concrete seal (DIRS 104523-CRWMS M&O 1999, p. 4-78). The analysis assumed that two seals per year would be produced. Table G-12 lists activities associated with the concrete batch facility and their emissions. Table G-33 lists emissions from the concrete batch facility during closure. Table G-34 lists potential air quality impacts as pollutant concentration in air and percent of regulatory limit.

Table G-33. Dust release rates from the concrete batch facility during the closure phase (PM_{10}).[a]

Period	Mass of pollutant (kilograms)[b]	Emission rate (grams per second)[c]
Annual	1,300	0.043
24-hour	120	11[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on a 3-hour release period.

Dust emissions from the concrete batch facility during closure would produce small offsite (outside the land withdrawal area) PM_{10} concentrations. The annual and 24-hour average concentrations of PM_{10} would be less than 1 percent and around 1.3 percent, respectively, of the regulatory standards.

For Modules 1 and 2, the estimated air quality impacts from the concrete batch facility during the closure phase would be the same as those for the Proposed Action.

Table G-34. Particulate matter (PM_{10}) air quality impacts from the concrete batch facility during the closure phase (micrograms per cubic meter).

Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Annual	0.0051	50	0.01
24-hour	1.9	150	1.3

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

G.1.6.3 Fugitive Dust from Closure Activities

Closure activities such as smoothing and reshaping the excavated rock pile and demolishing buildings would produce virtually the same fugitive dust releases as construction activities because they would disturb nearly the same amount of land. Sources of dust from surface demolition and decommissioning activities would include the North Portal area and roads, South portal area and roads, ventilation shaft areas and access roads, the excavated rock pile, solar power generating facility, concrete batch plant and, for some aspects of the lower-temperature operating mode, concrete spent nuclear fuel aging pads. Because some of these surface facilities would be needed to support subsurface closure activities, releases from surface demolition and decommissioning would last for the duration of the closure phase, not just the 6 years of closure at the North Portal Operations Area. Potential dust releases and impacts from the lower-temperature operating mode would be somewhat lower than from the higher-temperature operating mode because a similar scope of activities would occur over the longer closure phase. Dust release rates and potential air quality impacts are listed in Tables G-35 and G-36, respectively.

Table G-35. Fugitive dust releases from surface demolition and decommissioning (PM_{10}).[a]

Operating mode	Period	Pollutant emission (kilograms)[b]	Emission rate (grams per second)[c]
Higher-temperature	Annual	62,000 per year	2
	24-hour	250 per day	8.6[d]
Lower-temperature	Annual	52,000 - 60,000 per year	1.6 - 1.9
	24-hour	210 - 240 per day	7.3 - 8.3[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on an 8-hour release period.

Table G-36. Estimated fugitive dust air quality impacts (micrograms per cubic meter) from surface demolition and decommissioning (PM_{10}).[a]

Operating mode	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of limit[a]
Higher-temperature	Annual	0.24	50	0.47
	24-hour	1.6	150	1.1
Lower-temperature	Annual	0.2 - 0.23	50	0.4 - 0.46
	24-hour	1.4 - 1.6	150	0.92 - 1.1

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

Fugitive dust emissions would produce small offsite PM_{10} concentrations. The annual and 24-hour average concentrations of PM_{10} would be less than 0.5 percent and around 1.1 percent, respectively, of the regulatory standards. The estimated air quality impacts from surface facility closure for Inventory Modules 1 and 2 would be the same as those for the Proposed Action.

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G.1.6.4 Fugitive Dust from Excavated Rock Pile

During backfill operations, fugitive dust would occur from the removal of excavated rock from the storage pile. The analysis used the same method to estimate fugitive dust emission from the excavated rock pile during the closure phase that it used for the construction phase (Section G.1.4.3). Table G-37 lists the total area of the excavated rock pile disturbed and the active portion, based on the amount of material to be removed from the pile (DIRS 104523-CRWMS M&O 1999, p. 6-39; DIRS 150941-CRWMS M&O 2000, p. 6-24). The analysis assumed that the rock used in backfill would be from a limited area of the excavated rock pile, rather than from all over the pile. Table G-38 lists fugitive dust releases from the excavated rock pile. Table G-39 lists potential air quality impacts from the pile as pollutant air concentration and percent of regulatory limit.

Table G-37. Characteristics of excavated rock pile during the closure phase.[a]

Operating mode	Rock pile area (square kilometers)[b]	Pile height (meters)[c]	Annual average active area (square kilometers)
Higher-temperature	0.39	6	0.077
Lower-temperature	0.54 - 0.83	8	0.059 - 0.065

a. Numbers are rounded to two significant figures.
b. To convert square kilometers to acres, multiply by 247.1.
c. To convert meters to feet, multiply by 3.2808.

Table G-38. Fugitive dust release rates from the excavated rock pile during the closure phase (PM_{10}).[a]

Operating mode	Period	Emission (kilograms)[b]	Emission rate[c] (grams per second)[d]
Higher-temperature	Annual	11,000	0.35
	24-hour	30	0.35
Lower-temperature	Annual	8,300 - 9,200	0.26 - 0.29
	24-hour	23 - 25	0.26 - 0.29

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on a continuous release.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-39. Fugitive dust (PM_{10}) and cristobalite air quality impacts from the excavated rock pile during the closure phase (micrograms per cubic meter).

Operating mode	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
PM_{10}				
Higher-temperature	Annual	0.042	50	0.084
	24-hour	0.36	150	0.24
Lower-temperature	Annual	0.032 - 0.035	50	0.064 - 0.070
	24-hour	0.27 - 0.30	150	0.18 - 0.20
Cristobalite				
Higher-temperature	Annual	0.012	10[c]	0.12
Lower-temperature	Annual	0.0089 - 0.0098	10[c]	0.089 - 0.098

a. Numbers are rounded to two significant figures.
b. Source: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.
c. This value is a benchmark; there is no regulatory limit for cristobalite. See Section G.1.

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Fugitive dust emissions from the excavated rock pile during closure would produce small offsite PM_{10} concentrations. Both the annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards for all operating modes.

Table G-39 also lists potential air quality impacts for releases of cristobalite. The methods used were the same as those described in Section G.1.4.2 for the construction phase, where cristobalite was assumed to be 28 percent of the fugitive dust released, based on its percentage in parent rock. The land withdrawal area boundary cristobalite concentration would be small, about 0.1 percent of the benchmark level discussed in Section G.1.

For Modules 1 and 2, the same technique was used. The estimated active area of the rock pile would be 13 percent larger for the higher-temperature repository operating mode and 12 to 30 percent larger for the lower-temperature repository operating mode. The estimated air quality impacts would be just slightly larger than those of the Proposed Action because of longer closure times under Modules 1 and 2. Impacts would be less than 1 percent of the regulatory standards.

G.1.6.5 Exhaust Emissions from Surface Equipment

The consumption of diesel fuel by surface equipment and backfilling equipment would emit the four criteria pollutants during closure. The analysis used the same method to determine pollutant release rates during closure as was used for the construction phase (see Section G.1.4.5). Table G-15 lists the estimated pollutant release rates of the equipment that would consume the fuel. Table G-40 lists the average amount of fuel consumed per year. The length of the closure phase is discussed in Section G.1.6. The analysis assumed backfilling operations would last 2 years (DIRS 150941-CRWMS M&O 2000, p. I-2).

Table G-40. Annual amount of fuel consumed (liters)[a] during the closure phase.[b]

Operating mode	South Portal diesel	North Portal diesel[d]	Backfilling diesel[e,f]	Maximum annual usage
Higher-temperature	150,000[c]	620,000	1,250,000	2,000,000
Lower-temperature	150,000-170,000[g]	620,000	1,250,000	2,000,000

a. To convert liters to gallons, multiply by 0.26418.
b. Numbers are rounded to two significant figures.
c. Source: Based on total fuel consumed from DIRS 150941-CRWMS M&O (2000, p. 6-23).
d. Source: Based on total fuel consumed from DIRS 152010-CRWMS M&O (2000, p. 57).
e. Source: Based on total fuel consumed from DIRS 150941-CRWMS M&O (2000, p. I-2).
f. Backfilling operations would last only 2 years.
g. Source: Based on total fuel consumed from DIRS 155515-Williams (2001, Part 1, p. 25; and Part 2, p. 22).

Tables G-41 and G-42 list pollutant releases from surface diesel consumption. Table G-43 lists potential air quality impacts as pollutant concentrations in air and percent of regulatory limit. Concentrations would be less than 1 percent of the regulatory limit for the range of operating modes.

G.1.7 RETRIEVAL SCENARIO

This section describes the method used to estimate air quality impacts during possible retrieval at the proposed repository. Retrieval is not part of the Proposed Action; DOE evaluated it only as a contingent action of the higher-temperature operating mode. The retrieval contingency would last 14 years and include additional construction activities and retrieval operations. Construction of the retrieval storage facility and pads would take 10 years (DIRS 152010-CRWMS M&O 2000, p. I-17). There would be an initial 3-year period of construction (DIRS 152010-CRMWS M&O 2000, p. I-16), followed by 7 years of construction that would take place concurrently with retrieval operations. Retrieval operations would last

Table G-41. Pollutant release rates from surface equipment during the closure phase.[a]

Pollutant	Period	Mass of pollutant per averaging period (kilograms)[b] South	Mass of pollutant per averaging period (kilograms)[b] North	Emission rate[c] (grams per second)[d] South	Emission rate[c] (grams per second)[d] North
Higher-temperature operating mode					
Nitrogen dioxide	Annual	5,900	24,000	0.19	0.76
Sulfur dioxide	Annual	560	2,300	0.018	0.073
	24-hour	2.2	9.2	0.078	0.32
	3-hour	0.84	3.4	0.078	0.32
Carbon monoxide	8-hour	9.1	37	0.31	1.3
	1-hour	1.1	4.6	0.31	1.3
PM_{10}	Annual	520	2,100	0.017	0.068
	24-hour	2.1	8.6	0.073	0.3
Lower-temperature operating mode					
Nitrogen dioxide	Annual	5,900 - 6,600	24,000	0.19 - 0.21	0.76
Sulfur dioxide	Annual	560 - 625	2,300	0.018 - 0.02	0.073
	24 - hour	2.2 - 2.5	9.2	0.078 - 0.087	0.32
	3 - hour	0.84 - 0.94	3.4	0.078 - 0.087	0.32
Carbon monoxide	8 - hour	9.1 - 10	37	0.31 - 0.35	1.3
	1 - hour	1.1 - 1.3	4.6	0.31 - 0.35	1.3
PM_{10}	Annual	520 - 580	2,100	0.017 - 0.018	0.068
	24 - hour	2.1 - 2.3	8.6	0.073 - 0.081	0.3

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release period for averaging periods of 24 hours or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

Table G-42. Pollutant release rates from diesel backfilling equipment during the closure phase for the higher- and lower-temperature repository operating modes.[a]

Pollutant	Period	Mass of pollutant per averaging time (kilograms)[b]	Emission rate[c] (grams per second)[d]
Nitrogen dioxide	Annual	49,000	1.6
Sulfur dioxide	Annual	4,700	0.15
	24-hour	19	0.65
	3-hour	7.0	0.65
Carbon monoxide	8-hour	75	2.6
	1-hour	9.4	2.6
PM_{10}	Annual	4,400	0.14
	24-hour	17	0.60

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release for averaging periods of 24 hours or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

11 years (DIRS 152010-CRMWS M&O 2000, p. I-17), continuing 4 years after the construction was completed. If the lower-temperature operating mode with aging was implemented, the aging pads constructed could be used for storage of retrieved waste packages. The analysis considered concurrent air quality impacts of retrieval and construction. The retrieval scenario work schedule would be one 8-hour shift a day, 5 days a week, 50 weeks a year.

The analysis estimated air quality impacts by calculating pollutant concentrations from various activities associated with retrieval. Emission rates were developed for each activity that would result in releases of pollutants. These rates were multiplied by the unit release concentration (see Section G.1.3) to calculate pollutant concentrations for comparison to the various regulatory limits. The principal sources of particulates would be fugitive dust emissions from construction activities associated with the waste retrieval facility, and a concrete batch facility. The principal source of nitrogen dioxide, sulfur dioxide, and carbon monoxide would be fuel combustion during the construction of the waste retrieval facility and during retrieval of the waste. The following sections describe these sources in more detail.

Table G-43. Air quality impacts (micrograms per cubic meter) from surface equipment during the closure phase.

Pollutant	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Higher-temperature operating mode				
Nitrogen dioxide	Annual	0.3	100	0.3
Sulfur dioxide	Annual	0.029	80	0.037
	24-hour	0.2	365	0.055
	3-hour	1.6	1,300	0.12
Carbon monoxide	8-hour	2.4	10,000	0.024
	1-hour	14	40,000	0.035
PM_{10}	Annual	0.027	50	0.054
	24-hour	0.19	150	0.12
Lower-temperature operating mode				
Nitrogen dioxide	Annual	0.3 - 0.31	100	0.31
Sulfur dioxide	Annual	0.029	80	0.037
	24-hour	0.20	365	0.055
	3-hour	1.6	1,300	0.12
Carbon monoxide	8-hour	2.4	10,000	0.024
	1-hour	14	40,000	0.035
PM_{10}	Annual	0.027	50	0.054
	24-hour	0.19	150	0.12

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

G.1.7.1 Fugitive Dust from Construction of Retrieval Storage Facility

Construction activities such as earth moving and truck traffic would produce fugitive dust during the construction of the retrieval storage facility. The analysis used the same method to estimate fugitive dust releases during retrieval as that for construction (see Section G.1.4.1). The amount of land disturbed to build the retrieval storage facility and storage pads would be 1.5 square kilometer (380 acres) (DIRS 152010-CRWMS M&O 2000, Table I-2, p. I-22).

Table G-44 lists fugitive dust release rates from construction of the retrieval facility and storage pad. Table G-45 lists air quality impacts as pollutant concentration in air and percent of regulatory limit. Fugitive dust emissions from construction of the retrieval facility and storage pad would produce small offsite (outside the land withdrawal area) PM_{10} concentrations. Annual and 24-hour average concentrations of PM_{10} would be less than 1 percent of the regulatory standards for all operating modes.

Table G-44. Fugitive dust release rates from surface construction of retrieval storage facility and storage pad (PM_{10}).[a]

Period	Pollutant emission (kilograms)[b]	Emission rate (grams per second)[c]
Annual	34,000 per year	1.1
24-hour	140 per day	4.8[d]

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert grams per second to pounds per hour, multiply by 7.9366.
d. Based on an 8-hour release period.

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Table G-45. Fugitive dust (PM_{10}) air quality impacts from surface construction of the retrieval storage facility and storage pad (micrograms per cubic meter).

Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Annual	0.11	50	0.22
24-hour	0.87	150	0.58

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

G.1.7.2 Concrete Batch Plant

The concrete batch plant used during the retrieval phase was assumed to operate 3 hours per day, 250 days per year. The emissions would be approximately 85 percent of those indicated for the higher-temperature repository operating mode concrete batch plant during the construction phase (see Tables G-13 and G-14). The numbers would be lower because of the lower daily operating time (3 hours per day rather than 3.5 hours per day). The annual and 24-hour averaged concentrations of PM_{10} from the concrete batch plant would be less than 1 percent and 2 percent of the regulatory standards, respectively.

G.1.7.3 Exhaust from Surface Equipment

Surface equipment would emit the four criteria pollutants during retrieval operations and during the construction of the retrieval storage facility and storage pad. The analysis used the same method to estimate pollutant release rates from fuel consumed by construction equipment during retrieval that was used for the construction phase (see Section G.1.4.5). During retrieval operations, fuel would be consumed at the South Portal Development Area; during the construction of the retrieval facility and storage pad, fuel would be consumed at the North Portal Operations Area. Table G-15 lists the pollutant release rates of the equipment that would consume the diesel fuel. The fuel would be used for surface construction and surface and subsurface retrieval operations. Total annual usage for the Proposed Action would be 250,000 liters (66,000 gallons) of diesel fuel at the South Portal; 190,000 liters (50,000 gallons) at the North Portal; and 18,000 liters (4,800 gallons) for retrieval operations at the North Portal.

Table G-46 lists pollutant release rates for surface equipment during retrieval. Table G-47 lists the potential air quality impacts. Emissions from surface equipment during retrieval would produce small offsite criteria pollutant concentrations. All concentrations would be less than 1 percent of the regulatory standards.

Table G-46. Pollutant release rates from surface equipment during the retrieval scenario.[a]

Pollutant	Period	Mass of pollutant per averaging time (kilograms)[b]	Emission rate[c] (grams per second)[d]
Nitrogen dioxide	Annual	9,100	0.29
Sulfur dioxide	Annual	860	0.027
	24-hour	3.4	0.12
	3-hour	1.3	0.12
Carbon monoxide	8-hour	14	0.48
	1-hour	1.7	0.48
PM_{10}	Annual	800	0.025
	24-hour	3.2	0.11

a. Numbers are rounded to two significant figures.
b. To convert kilograms to pounds, multiply by 2.2046.
c. Based on an 8-hour release period for averaging periods of 24 hour or less.
d. To convert grams per second to pounds per hour, multiply by 7.9366.

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Table G-47. Air quality impacts from surface equipment during the retrieval scenario (micrograms per cubic meter of pollutant).

Pollutant	Period	Maximum concentration[a]	Regulatory limit[b]	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.035	100	0.035
Sulfur dioxide	Annual	0.003	80	0.0042
	24-hour	0.023	365	0.0062
	3-hour	0.18	1,300	0.014
Carbon monoxide	8-hour	0.28	10,000	0.0027
	1-hour	1.6	40,000	0.004
PM_{10}	Annual	0.0031	50	0.0061
	24-hour	0.021	150	0.014

a. Numbers are rounded to two significant figures.
b. Sources: 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391.

G.2 Radiological Air Quality

This section describes the methods DOE used to analyze potential radiological impacts to air quality at the proposed Yucca Mountain Repository during the construction, operation and monitoring, and closure phases, and a possible retrieval scenario. The results are presented in Chapter 4, Section 4.1.2. It discusses the radioactive noble gas krypton-85, which would be released from surface facilities during the handling of spent nuclear fuel, and naturally occurring radon-222 and its radioactive decay products, which would be released from the rock to the subsurface facility and then to the ventilation air. The excavated rock pile would not be a notable additional source of radon-222, because the rock would not have enhanced concentrations of uranium or radium (the sources of radon-222) in comparison to surface rock. Somewhat higher concentrations of radon-222 could be present at the rock pile itself but, in general, concentrations of radon-222 released from the excavated rock pile would not differ greatly from naturally occurring surface concentrations of radon.

G.2.1 LOCATIONS OF HYPOTHETICALLY EXPOSED INDIVIDUALS AND LOCATIONS

Members of the public and noninvolved workers could be exposed to atmospheric releases of radionuclides from repository activities. Doses to the maximally exposed individual and population within 80 kilometers (50 miles) were evaluated for the public. The dose to the maximally exposed noninvolved worker and the noninvolved worker populations at the repository and at the Nevada Test Site were also evaluated.

Public

The location of the maximally exposed individual member of the public would be at the southern boundary of the land withdrawal area. This was determined to be the location of unrestricted public access that would have the highest annual average concentration of airborne radionuclides (see Section G.2.2). Twenty kilometers (12 miles) was used as a representative distance to the exposed individual location for releases to air from the North Portal, South Portal, and one to nine exhaust ventilation shafts over three project phases and the range of operating modes. The locations calculated for nonradiological air quality impacts (Section G.1.2) are somewhat different because the analysis estimated exposure to nonradiological pollutants for acute (short-term) exposures (1 to 24 hours) and for annual (continuous) exposures.

Table G-48 lists the estimated population of about 76,000 within 80 kilometers (50 miles) of the repository. This is the predicted population for 2035, based on projected changes in the region, including the towns of Beatty, Pahrump, Indian Springs, and the surrounding rural areas. These projections are based on information from State and local sources (see Chapter 3, Section 3.1.7) The population in the vicinity of Pahrump was included in Table G-48 and evaluated for air quality impacts, even though the population extends beyond the 80-kilometer region. The analysis calculated both annual population dose and cumulative dose for the project phases of 115 to 341 years of construction, operation and monitoring, and closure.

Table G-48. Projected 2035 population distribution within 80 kilometers (50 miles) of repository site.[a,b,c]

	Distance (kilometers)										
Direction	8	16	24	32	40	48	56	64	72	80	***Totals***
S	0	0	49	660	1,376	363	0	19	0	0	***2,467***
SSW	0	0	0	928	179	0	0	4	0	0	***1,111***
SW	0	0	0	0	0	0	596	62	0	0	***658***
WSW	0	0	0	0	0	0	0	0	107	0	***107***
W	0	0	0	1,092	10	0	0	0	0	0	***1,102***
WNW	0	0	63	1,829	0	0	0	0	0	11	***1,903***
NW	0	0	0	50	2	0	0	5	50	0	***105***
NNW	0	0	0	0	0	0	0	0	0	0	***0***
N	0	0	0	0	0	0	0	0	0	0	***0***
NNE	0	0	0	0	0	0	0	0	0	0	***0***
NE	0	0	0	0	0	0	0	0	0	0	***0***
ENE	0	0	0	0	0	0	0	0	0	0	***0***
E	0	0	0	0	0	0	0	0	0	0	***0***
ESE	0	0	0	0	0	0	0	0	2,686	0	***2,686***
SE	0	0	0	0	0	0	50	0	0	1,086	***1,136***
SSE	0	0	0	0	41	187	49	177	18,249	46,080[d]	***64,783***
Grand Total											***76,058***

a. Source: DIRS 155105-Baxter (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. There is a 4-kilometer (about 2.5-mile)-radius area around the North Portal, from which the analysis determined the 80-kilometer (50-mile) area.
d. Includes the Pahrump vicinity population, which extends beyond the 80-kilometer region.

Noninvolved (Surface) Workers

The analysis assumed noninvolved workers on the surface would be at the site 2,000 hours a year (8 hours a day, 5 days a week, 50 weeks a year), or about 23 percent of the total number of hours in a year (8,760). All surface workers, regardless of work responsibility, were considered to be noninvolved workers for evaluation of exposure to radon-222 and radon decay products released from the subsurface facilities. For releases of noble gases (principally krypton-85) from spent fuel handling activities, potentially exposed noninvolved workers would be all surface workers except those in the Waste Handling and Waste Treatment Buildings. The noble gases would be released from the Stack of the Waste Handling Building and workers in these facilities would not be exposed.

The maximally exposed noninvolved worker location for releases of radon and its decay products would be in the South Portal Development Area for all project phases. During the construction phase and development activities ventilation air from repository excavation activities would be exhausted through the South Portal, resulting in the highest potential exposure to radon and radon decay products. The analysis assumed that during these periods this worker would be in the office building about 100 meters (330 feet) northeast of the South Portal. This location is not directly in front of the South Portal but offset from what would be the ventilation plume centerline, so the atmospheric dispersion factor is reduced somewhat (see Section G.2.2). There would be no South Portal ventilation during monitoring activities and the closure phase, but the maximally exposed noninvolved worker would still be in the South Portal Development Area. For releases from the Waste Handling Building during spent fuel handling operations, the maximally exposed noninvolved worker location would be in the North Portal

Operations Area. When both surface and subsurface sources of radionuclides during operations are considered, the maximally exposed worker location would be the South Portal Development Area.

The population and distribution of repository workers required to staff the repository would depend on the specific parameters of the operating mode. The highest labor requirements listed in Table G-49 would be for the lower-temperature operating mode with spent fuel aging. The lowest labor requirements would be for the higher-temperature operating mode.

Table G-49. Noninvolved (surface) worker population distribution for Yucca Mountain air quality analyses.[a,b,c,d]

		Fulltime equivalent worker years	
		Operating mode	
Worker location	Time period	Higher-temperature	Lower-temperature
Construction phase	5 years		
North Portal		4,000	3,800 - 4,100
South Portal		490	490
Operation and monitoring			
Emplacement and development			
North Portal (exposure to subsurface releases)	24 or 50 years[e]	31,000	31,000 - 50,000
South Portal	24 years	1,500	1,600 - 2,100
North Portal (exposure to WHB/WTB releases)	24 years	8,200[d]	8,200 - 9,100[f]
Monitoring and maintenance			
North Portal – decontamination	3 years	3,400	2,800 - 3,400
North Portal – monitoring and maintenance	73 - 297 years	2,800	3,700 - 11,000
South Portal	76 - 300 years	930	1,200 - 3,700
Closure			
North Portal	6 years	4,000	4,000
South Portal	10 - 17 years	420	470 - 720
Retrieval[g]			
North Portal – construction	10 years	1,800	(h)
North Portal – operations	11 years	1,200	(h)
South Portal – operations	11 years	150	(h)

a. Sources: Appendix F, Table F-3 and DIRS 150941-CRWMS M&O (2000, p. 4-52).
b. Numbers are rounded to two significant figures.
c. Fifteen percent of fulltime equivalent subsurface worker time would be spent on the surface in the South Portal Development Area (based on DIRS 150941-CRWMS M&O (2000, p. 4-52).
d. Fulltime equivalent worker years for the time period listed.
e. 50 years for aging only.
f. Total workers exposed to krypton-85 releases from surface facilities. All noninvolved workers, does not include involved workers in Waste Handling or Waste Treatment Buildings; includes 15 percent of subsurface workers.
g. The retrieval period would last 14 years. There would be 3 years of initial construction followed by 7 additional years of construction during operations. Retrieval operations would last 11 years. Sources: DIRS 152010-CRWMS M&O (2000, pp. I-16 to I-20); DIRS 150941-CRWMS M&O (2000, pp. 6-19 to 6-20).
h. The retrieval contingency is not a part of the Proposed Action. Results are in Chapter 4, Section 4.2.1.2.2.

The estimated population of workers in the South Portal Development Area was based on the number of full-time equivalents of subsurface workers. This would include full-time South Portal Development Area workers as well as workers who would be on the surface for only a portion of a day as they prepared for underground work. The number of subsurface workers located in the South Portal Development Area was estimated to be 15 percent of the total subsurface workers. Also evaluated as a potentially exposed noninvolved worker population were DOE workers at the Nevada Test Site. The analysis used a Nevada Test Site worker population of 6,576 workers (DIRS 101811-DOE 1996, Volume I, Appendix A, p. A-69).

For purposes of analysis, all these workers were assumed to be about 50 kilometers (30 miles) east-southeast of the repository at Mercury, Nevada.

G.2.2 METEOROLOGICAL DATA AND ATMOSPHERIC DISPERSION FACTORS

The basis for the atmospheric dispersion factors used in the dose calculations was a joint frequency distribution file for 1993 to 1997. These data were based on site-specific meteorological measurements made at air quality and meteorology monitoring Site 1, combined for 1993 to 1997 (DIRS 102877-CRWMS M&O 1999, p. 11). Site 1 is about 1 kilometer (0.6 mile) south of the proposed North Portal surface facility location. Similar topographic exposure would lead to similar prevailing northerly and southerly winds at both locations. DOE used these data because an analysis of the data collected at all the sites showed Site 1 to be most representative of the surface facilities (DIRS 102877-CRWMS M&O 1999, p. 7). The joint frequency data are somewhat different from the more detailed meteorological data used for the nonradiological air quality analysis. The dose calculations required only annual average data because they compare doses to annual limits, whereas criteria pollutant limits have 1-, 3-, 8-, or 24-hour averaging periods and the calculation of short-term criteria pollutant concentrations required hourly meteorological data. The nonradiological analysis also calculated concentrations only at the land withdrawal area boundary, not at onsite locations where workers would be.

Depending on the operating mode, project phase, and level of activity, subsurface ventilation air could be exhausted from three to nine exhaust shafts and the South Portal. These exhaust shafts would be on the ridge above the repository. Table G-50 lists the distribution of exhaust ventilation air among the subsurface release points for the operating modes and project phases and activities. These distributions were used to calculate annual average atmospheric dispersion factors for radon releases from the subsurface.

The GENII software system (DIRS 103821-Napier et al. 1988, all) was used to calculate annual average atmospheric dispersion factors for radon released from the subsurface exhaust points and for noble gases released from the Waste Handling Building stack. The releases from the South Portal would be at ground level, while releases from the exhaust shafts on the ridge above the repository were modeled as 60-meter (200-foot) releases. Noble gas releases from the Waste Handling Building would be from a 60-meter (200-foot) stack, also modeled as an elevated release. Table G-51 lists the atmospheric dispersion factors for the radon and krypton-85 release points at the site that incorporate the release distribution data in Table G-50. The radon dispersion factors would vary among combinations of operating mode and project phase because of the differences in release point contributions noted in Table G-50. Population dispersion factors have been normalized to be independent of the population size. The population distribution data in Tables G-48 and G-49 can be used with the atmospheric dispersion factors to calculate population-weighted dispersion factors for public and noninvolved worker populations, from which collective doses can be calculated.

G.2.3 RADIOLOGICAL SOURCE TERMS

There would be two distinctly different types and sources of radionuclides released to the air from activities at the repository. Naturally occurring radon-222 and its radioactive decay products would be released from the subsurface facility during all phases as the repository ventilation system removed airborne particulates from development operations and exhausted air heated by the emplaced materials. Radioactive noble gases would be released from commercial spent nuclear fuel during handling and transfer operations in the surface facilities during the operation and monitoring phase. Section G.2.3.1 discusses the releases of radon-222 and radon decay products. Section G.2.3.2 discusses the releases of radioactive noble gases from commercial spent nuclear fuel.

Table G-50. Distribution (percent) of repository subsurface exhaust ventilation air.[a,b]

Operating mode, release point	Construction	Concurrent development and emplacement	Emplacement only; and monitoring	Closure
Proposed Action: higher-temperature				
South Portal	100	30	NA[c]	NA
Exhaust Shaft 1	NA	40	33.3	33.3
Exhaust Shaft 2	NA	20	33.3	33.3
Exhaust Shaft 3	NA	10	33.3	33.3
Proposed Action: lower- temperature maximum ventilation; Inventory Modules 1 and 2: higher-temperature				
South Portal	100	30	NA	NA
Exhaust Shaft 1	NA	20	16.7	16.7
Exhaust Shaft 2	NA	15	16.7	16.7
Exhaust Shaft 3	NA	10	16.7	16.7
Exhaust Shaft 4	NA	10	16.7	16.7
Exhaust Shaft 5	NA	10	16.7	16.7
Exhaust Shaft 6	NA	5	16.7	16.7
Proposed Action: lower-temperature maximum waste package spacing; Inventory Modules 1 and 2: lower-temperature operating mode				
South Portal	100	20	NA	NA
Exhaust Shaft 1	NA	10	11.1	11.1
Exhaust Shaft 2	NA	10	11.1	11.1
Exhaust Shaft 3	NA	10	11.1	11.1
Exhaust Shaft 4	NA	10	11.1	11.1
Exhaust Shaft 5	NA	10	11.1	11.1
Exhaust Shaft 6	NA	5	11.1	11.1
Exhaust Shaft L1	NA	10	11.1	11.1
Exhaust Shaft L2	NA	10	11.1	11.1
Exhaust Shaft L3	NA	5	11.1	11.1

a. Sources: Derived from DIRS 153849-DOE (2001, pp. 2-139 to 2-147); DIRS 155515-Williams (2001, Part 1, pp. 6 to 7, Part 2, pp. 5 to 6).
b. Exhaust shaft releases are elevated; portal releases are ground-level.
c. NA = not applicable.

G.2.3.1 Release of Radon-222 and Radon Decay Products from the Subsurface Facility

In the subsurface facility the noble gas radon-222 would diffuse continually from the rock into the air of the repository drifts. Radioactive decay of the radon in the air of the drift would produce radon decay products, which would begin to come into equilibrium (having the same activity) with the radon-222 because their radioactive half-lives are much shorter than the 3.8-day half-life of radon-222. Key radionuclide members of the radon-222 decay chain are polonium-218 and polonium-214, with half-lives of 3.05 minutes and 164 microseconds, respectively. Exhaust ventilation would carry the radon-222 and the radon decay products from the repository.

The estimates of radon-222 and its decay product releases were based on concentration observations made in the Exploratory Studies Facility subsurface areas during site characterization and subsequent analyses of these data (DIRS 150246-CRWMS M&O 2000, all; DIRS 154176-CRWMS M&O 2000, all). These two reports have significantly expanded the available information on radon-222 flux into the repository, radon concentrations in the repository, and radon release from the repository.

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Table G-51. Atmospheric dispersion factors (seconds per cubic meter) for potentially exposed individuals and populations.[a,b,c]

Operating mode, receptor	Receptor location	Construction	Operation and monitoring: Concurrent development and emplacement	Operation and monitoring: Emplacement only; and monitoring	Closure
Repository radon releases					
Proposed Action, higher-temperature					
Public MEI[d]	(e)	2.2×10^{-8}	1.1×10^{-8}	6.0×10^{-9}	6.0×10^{-9}
Public population	80 km[f] radius	4.8×10^{-9}	2.3×10^{-9}	1.3×10^{-9}	1.3×10^{-9}
Worker MEI	South Portal	6.2×10^{-5}	1.9×10^{-5}	1.8×10^{-8}	1.8×10^{-8}
Worker population	South Portal	3.1×10^{-5}	9.3×10^{-6}	1.8×10^{-8}	1.8×10^{-8}
Worker population	North Portal	2.7×10^{-7}	8.9×10^{-8}	1.1×10^{-8}	1.1×10^{-8}
Nevada Test Site worker population	50 km east-southeast	6.9×10^{-10}	4.0×10^{-10}	2.7×10^{-10}	2.7×10^{-10}
Proposed Action: lower-temperature maximum ventilation; Inventory Modules 1 and 2: higher-temperature					
Public MEI	(e)	2.2×10^{-8}	1.1×10^{-8}	6.0×10^{-9}	6.0×10^{-9}
Public population	80 km radius	4.7×10^{-9}	2.3×10^{-9}	1.3×10^{-9}	1.3×10^{-9}
Worker MEI	South Portal	6.2×10^{-5}	1.9×10^{-5}	2.1×10^{-8}	2.1×10^{-8}
Worker population	South Portal	3.1×10^{-5}	9.3×10^{-6}	2.1×10^{-8}	2.1×10^{-8}
Worker population	North Portal	2.7×10^{-7}	9.0×10^{-8}	1.5×10^{-8}	1.5×10^{-8}
Nevada Test Site worker population	50 km east-southeast	6.9×10^{-10}	4.0×10^{-10}	2.7×10^{-10}	2.7×10^{-10}
Proposed Action: lower-temperature maximum waste package spacing; Inventory Modules 1 and 2: lower-temperature					
Public MEI	(e)	2.2×10^{-8}	9.2×10^{-9}	6.0×10^{-9}	6.0×10^{-9}
Public population	80 km radius	4.8×10^{-9}	2.0×10^{-9}	1.3×10^{-9}	1.3×10^{-9}
Worker MEI	South Portal	6.2×10^{-5}	1.2×10^{-5}	2.9×10^{-8}	2.9×10^{-8}
Worker population	South Portal	3.1×10^{-5}	6.2×10^{-6}	2.9×10^{-8}	2.9×10^{-8}
Worker population	North Portal	2.7×10^{-7}	6.9×10^{-8}	2.1×10^{-8}	2.1×10^{-8}
Nevada Test Site worker population	50 km east-southeast	6.9×10^{-10}	3.5×10^{-10}	2.7×10^{-10}	2.7×10^{-10}
Waste Handling Building stack releases				Operations	
Public MEI	(e)			6.0×10^{-9}	
Public population	80 km radius			1.3×10^{-9}	
Worker MEI	North Portal			3.2×10^{-7}	
Worker population	North Portal			3.2×10^{-7}	
Worker MEI	South Portal			6.4×10^{-8}	
Worker population	South Portal			6.4×10^{-8}	

a. Numbers are rounded to two significant figures.
b. Includes contribution and distribution from all operating exhaust shafts and portals. Stack and exhaust shaft releases would be elevated; south portal releases would be ground-level.
c. Dispersion factors have been normalized for populations. Multiply times the population to get the population dispersion factor.
d. MEI = maximally exposed individual.
e. Located at the southern boundary of the land withdrawal area.
f. km = kilometer; to convert kilometers to miles, multiply by 0.62137.

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The radon-222 flux into the repository would depend on many different parameters. One such parameter is the repository air pressure, which would depend on the ventilation flow rate. Air pressure, radon flux, and radon concentration were estimated for the portion of the repository ventilated by one exhaust shaft for the higher-temperature repository operating mode (DIRS 154176-CRWMS M&O 2000, pp. 18 to 25). These characteristics were assumed to be applicable for each area of the repository ventilated by an exhaust shaft, so the higher-temperature operating mode—with three exhaust shafts—would have three areas with these exhaust characteristics. Similar assumptions were made for the lower-temperature operating mode where the repository would be ventilated by six to nine exhaust shafts. The analysis modeled a fully excavated, functioning repository, but these characteristics would be representative of all repository phases. This assumption might tend to overestimate the actual release of radon from the repository.

From the above information, average radon flux and radon release values were determined for three major types of repository excavation. The distinctions, which are based on the diameter of the excavation, include 7.6-meter (25-foot) and similar diameter excavations, typical of main drifts, ramps, and ventilation shafts; 5.5-meter (18-foot) and similar diameter excavations, typical of emplacement, standby, and observation drifts; and 2-meter (6.6-foot) and similar diameter excavations, typical of ventilation raises. The estimated average radon fluxes for these excavation types would be 35, 41, and 41 picocuries per square meter of exposed rock area per second, respectively. As noted above, these fluxes were assumed to apply to the respective diameter excavations in all repository areas. The estimated average activity of radon emanating per year per meter of the respective excavation types would be 0.021, 0.022, and 0.008 curie per meter per year. Information on the length and volume of repository excavations during the construction phase and during subsequent development is available for the range of operating modes analyzed (DIRS 150941-CRWMS M&O 2000, pp. 6-5 and 6-10; DIRS 155515-Williams 2001, Part 1, pp. 11 and 16, and Part 2, pp. 9 and 14). The analysis assumed that lengths and volumes would increase linearly over the project periods during which excavation took place, namely the 5 years of the construction phase and 22 years of development during the operations period at the beginning of the operation and monitoring phase.

The analysis assumed that, during the construction phase and development activities, all excavated areas of the repository except the 5.5-meter (18-foot) drifts (emplacement drifts, etc.) would be lined with concrete. This liner would be a barrier to radon diffusion into the repository, which would reduce radon flux by 50 percent (DIRS 152541-Ikenberry 2000, all). The analysis assumed the liners would be added linearly to applicable areas of the repository throughout the construction phase and the development period. The only exception would be a portion of the South Main Drift and ramp, which would not be lined with concrete until late in the development period. The analysis also assumed that the liners throughout the repository would be maintained during the preclosure period to prevent and seal fractures and maintain the reduction in radon flux for applicable repository areas.

Construction Phase

Repository excavation and radon releases would be very similar for the operating modes during the 5 years of the construction phase. The initial Exploratory Studies Facility excavated volume of about 420,000 cubic meters (550,000 cubic yards) would increase to 1.7 million to 2.1 million cubic meters (2.2 million to 2.7 million cubic yards) by the end of the construction phase. Most of the excavation during this phase would be for the 7.6-meter (25-foot) drifts and shafts.

Operation and Monitoring Phase

Operations Period. The operations period would last 24 years without aging, 50 years with aging. Development activities would take place during the first 22 years of operation and monitoring. During this period an additional 2.7 million to 6.8 million cubic meters (3.5 million to 8.9 million cubic yards) of repository volume would be excavated (DIRS 150941-CRWMS M&O 2000, p. 6-10; DIRS 155515-Williams 2001, Part 1, pp. 11 and 16 and Part 2, pp. 9 and 14). The total excavated volume would range from 4.3 million to 8.8 million cubic meters (5.6 million to 11.5 million cubic yards). During development activities a sizeable amount of the excavation would be of the 5.5-meter (18-foot) emplacement drifts and other 5.5-meter excavations. The maximum annual radon release would begin following the completion of

Table G-52 lists the estimated releases of radon-222 and radon decay products annually and by project phase.

Table G-52. Estimated radon-222 releases for repository activities under the Proposed Action.

Project phase or period and operating mode	Annual average radon release[b] (curies)	Maximum annual radon release[b,c] (curies)	Total radon release[b] (curies)	Duration (years)
Total, all phases				
Higher-temperature	1,900		220,000	115
Lower-temperature	1,400 - 4,100		480,000 - 1,000,000	171 - 341
Construction Phase				
Higher-temperature	480	610	2,400	5
Lower-temperature	480 - 570	610 - 750	2,400 - 2,900	5
Operations period				
Higher-temperature	1,500	2,100	36,000	24
Lower-temperature	2,100 - 3,800	3,000 - 4,600	50,000 - 190,000	24, 50
Monitoring period				
Higher-temperature	2,100	2,100	160,000	76
Lower-temperature	1,000 - 4,600	1,000 - 4,600	410,000 - 940,000	99 - 300
Closure phase				
Higher-temperature	1,500	2,100	15,000	10
Lower-temperature	2,000 - 2,800	2,900 - 4,500	22,000 - 48,000	11 - 17
Retrieval scenario				
Higher-temperature[d]	2,100		30,000	14

a. Numbers are rounded to two significant figures; totals might not equal sums of values due to rounding.
b. Includes radon-222 and radon decay products.
c. In general, these maximum annual values occur only for a single year. The major exception is for monitoring.
d. Retrieval is not part of the Proposed Action and only the higher-temperature operating mode was evaluated.

excavation, lasting the final 2 years (no aging) or 26 years (aging) of the operations period, and continue through the monitoring period. Highest annual average radon releases during operations would come from 6.4-meter (21-foot) waste package spacing of the lower-temperature operating mode, which would have the largest development and total excavated repository volume. Use of spent nuclear fuel aging would result in the highest operations period releases because of the additional 26 years of operations required.

Monitoring Period. No excavation would take place during the monitoring period, and the ventilation flowrate would remain constant, as would the radon release rate.

Monitoring and maintenance activities would last 76 years for the higher-temperature operating mode and up to 300 years of the lower-temperature operating mode. The highest total releases during monitoring would occur because of a 300-year monitoring period with forced ventilation. The lowest monitoring period release would occur if 250 years of natural ventilation were used following 50 years of forced ventilation. Releases during the monitoring period would account for 75 to 92 percent of the total radon released over the entire project duration.

Closure Phase

Annual releases of radon-222 and radon decay products during the closure phase would decrease linearly over the phase as the repository was gradually closed. The initial release rate would be the same as the monitoring period release rate and the ending release rate would equal that at the start of the operations period. The decrease in release rate from beginning to end would be 70 to 80 percent. Differences in the lengths of the closure phase (ranging from 10 to 17 years) would lead to additional differences in the total amount of radon released.

Retrieval

Only the higher-temperature repository operating mode was evaluated for a postulated retrieval scenario. Estimated releases would occur over a 14-year period of construction and retrieval operations. The 10-year planning period preceding retrieval was assumed to occur during the monitoring period and was not included in the evaluation. The annual release rate of radon-222 and its decay products would be the same as that for the monitoring period.

Inventory Modules 1 and 2

Releases of radon-222 and its decay products for Inventory Modules 1 and 2 were estimated using the same methods as those used for the Proposed Action. The major differences would be the larger repository volumes, which would result in larger releases of radon. In addition, the project duration would be longer under the Proposed Action, with 38 years required to complete operations (which would include 36 years of development), and a longer closure phase. Table G-53 lists estimated radon releases. Releases of radon would be higher for the inventory modules than for the Proposed Action in all cases.

Table G-53. Estimated radon-222 releases for repository activities for Inventory Modules 1 or 2.[a]

Project phase and operating mode	Annual average radon release[b] (curies)	Maximum annual radon release[b,c] (curies)	Total radon release[b] (curies)	Duration (years)
Total, all phases				
Higher-temperature	2,600		300,000	117
Lower-temperature	2,100 - 6,200		760,000 - 1,600,000	191 - 359
Construction phase				
Higher-temperature	480	610	2,400	5
Lower-temperature	560 - 570	730 - 750	2,800 - 2,900	5
Operations period				
Higher-temperature	2,000	3,200	78,000	38
Lower-temperature	2,800 - 5,100	4,500 - 7,400	110,000 - 260,000	38 or 51
Monitoring period				
Higher-temperature	3,200	3,200	200,000	62
Lower-temperature	1,500 - 7,400	1,500 - 7,400	610,000 - 1,400,000	112 - 300
Closure phase				
Higher-temperature	2,100	3,100	25,000	12
Lower-temperature	2,800 - 4,300	4,400 - 7,300	44,000 - 98,000	15 - 23

a. Numbers are rounded to two significant figures; totals might not equal sums of values due to rounding.
b. Includes radon-222 and radon decay products.
c. In general these maximum annual values would occur only for a single year. The major exception would be for monitoring.

G.2.3.2 Release of Radioactive Noble Gases from the Surface Facility

The unloading and handling of commercial spent nuclear fuel would produce the only routine emissions of manmade radioactive materials from repository facilities. No releases would occur as a result of emplacement activities. Shipping casks containing spent nuclear fuel would be opened in the transfer pool of the Waste Handling Building at the North Portal Operations Area. During spent nuclear fuel handling and transfer, radionuclides could be released from a small percentage of fuel elements with pinhole leaks in the fuel cladding; only noble gases would escape the pool and enter the ventilation system of the Waste Handling Building (DIRS 104508-CRWMS M&O 1999, p. 17). The largest release of radionuclides from surface facilities would be krypton-85, with about 2,600 curies released annually. Releases of other noble gas radionuclides would be very small, with estimated annual releases of about 0.0000010 curie of krypton-81, 0.000033 curie of radon-219, 0.059 curie of radon-220, 0.0000046 curie of radon-222, and even smaller (negligible) quantities of xenon-127 (DIRS 152010-CRWMS M&O 2000, p. 52). The same annual releases would occur for both the Proposed Action and for the inventory modules. Of these radionuclides, krypton-85 would be by far the largest and most important dose contributor, from releases totaling 61,000 curies for the Proposed Action and 97,000 curies for the inventory modules. All spent nuclear fuel and high-level radioactive waste in disposable canisters would be transferred from shipping casks to disposal containers in shielded rooms (hot cells) in the Waste Handling Building. Because all DOE material would be in sealed disposable canisters, no radionuclide releases from these materials would occur.

Releases of noble gases from the surface facility would be the same for all operating modes. These estimated releases were based on the following assumptions for commercial spent nuclear fuel (DIRS 104508-CRWMS M&O 1999, p. 17):

- Pressurized-water reactor burnup of about 40 gigawatt-days per metric ton of uranium with 3.7-percent enrichment and an average of 26 years decay
- Boiling-water reactor burnup of 32 gigawatt-days per metric ton of uranium with 3-percent enrichment and an average of 27 years decay
- A failure rate of 0.25 percent for fuel assemblies in the canisters, allowing gaseous radionuclides (isotopes of krypton, radon, and xenon) to escape
- Radionuclides other than noble gases (such as cobalt-60, cesium-137, and strontium-90) would not escape the transfer pool if released from fuel assemblies

G.2.3.3 Release from Waste Packages Prior to Repository Closure

DOE examined the potential for release of radionuclides from failed waste packages and failed spent nuclear fuel during the operation and monitoring phase and the closure phase to determine if this would be another source of manmade radionuclides during the repository project.

DOE considered the potential for failure of waste packages and spent nuclear fuel cladding in detail in evaluating the long-term performance of the repository (see Chapter 5 and Appendix I). Section 5.5.1 notes that more than 99 percent of the cladding on spent nuclear fuel would be intact at the time it was placed in waste packages and emplaced in the repository. Appendix I, Section I.2.4, discusses the early failure of waste packages, and notes that a small number of waste packages (zero to three) could undergo early failure caused by improper heat treatment of the outer lid closure weld. This analysis is conservative and does not account for the inner lid weld or the inner barrier lid weld. For preclosure activities, it is assumed that the inner lid and the inner barrier lid welds are in place. Therefore, no releases from waste packages during the preclosure period are expected.

G.2.4 DOSE CALCULATION METHODOLOGY

The previous three sections provided information on the location and distribution of potentially affected individuals and populations (Section G.2.1), atmospheric dispersion (Section G.2.2), and the type and quantity of radionuclides released to air (Section G.2.3) in the Yucca Mountain region. The analysis used these three types of information to estimate the radionuclide concentration in air (in picocuries of radionuclide per liter of air) at a specific location or for an area where there would be a potentially exposed population. The estimation of the radiation dose to exposed individuals or populations from concentrations of radionuclides in air used this information and published dose factors. This section describes the concentration-to-dose conversion factors that the analysis used to estimate radiation dose to members of the public and noninvolved workers from releases of radionuclides at the repository.

G.2.4.1 Dose to the Public

The analysis estimated doses to members of the public using screening dose factors from the National Council on Radiation Protection and Measurements (DIRS 101882-NCRP 1996, Volume I, pp. 113 and 125). Use of these factors results in a conservative (tending to overestimate) estimate of the dose that could be received). The analysis considered all exposure pathways, including inhalation, ingestion, and direct external radiation from radionuclides in the air and on the ground. For noble gases released from the Waste Handling Building, krypton-85 would be by far the most important and largest dose contributor. Only direct external exposure from radionuclides in the air would be a contributing exposure pathway. The analysis estimated the dose from krypton-85 by multiplying 1) the radionuclide activity released 2) the atmospheric dispersion factor at the exposure location and 3) the radionuclide-specific dose factor, with appropriate unit conversions (for example, seconds per year or liters per cubic meter) included. Table G-54 lists the screening dose factor for krypton-85 for members of the public. The analysis assumed that members of the public would be exposed for 8,000 hours per year (DIRS 101882-NCRP 1996, Volume I, p. 61). Results are presented in Chapter 4, Section 4.1.2.

Table G-54. Factors for estimating dose to the public and noninvolved workers per concentration of radionuclide in air (millirem per picocurie per liter per hour) for krypton-85 and radon-222.[a,b]

Radionuclide	Public	Noninvolved worker
Krypton-85[c]	0.0000013	0.0000013
Radon-222[d]	0.25[e]	0.00091[f]

a. Numbers are rounded to two significant figures.
b. Dose factors for radon-222 include dose contribution from decay products.
c. Source: DIRS 101882-NCRP (1996, p. 113); normalized from exposure time of 8,000 hours per year (p. 61).
d. Source: DIRS 101882-NCRP (1996, p. 125); normalized from exposure time of 8,000 hours per year (ground exposure is one-fourth of total exposure) (p. 61).
e. Includes all exposure pathways.
f. Includes only the inhalation and plume exposure pathways.

The short-lived decay products of radon-222 would account for essentially the entire dose from radon and its decay products, and the degree to which the decay products would reach equilibrium with radon-222 and their total activity are important considerations. At release from the repository, the estimated average fraction of equilibrium reached would be 0.22 (DIRS 154176-CRWMS M&O 2000, attachment 4), or 22 percent of the radon-222 activity. Once released to the atmosphere, the decay product activity would begin to build toward equilibrium with the parent radon-222 activity with a halftime of about one-half hour. It is difficult to estimate the equilibrium fraction in this dynamic outdoor environment. A typical outdoor radon equilibrium level is 60 percent (DIRS 155699-NCRP 1984, p. 25), with a lower degree of equilibrium closer to the source. Although this value is for a continuous radon source emanating from the ground over an essentially infinite area, DOE used it as a conservative estimate of the equilibrium fraction. The analysis used the average annual wind speed of 2.5 to 4.4 meters per second (5.6 to 9.8 miles per hour) (see Chapter 3, Section 3.1.2.2) to estimate the radon decay product equilibrium fraction at the location of members of the public. It used 3 meters per second (6.7 miles per hour) as representative. The transit time to the location of the maximally exposed individual at the southern boundary of the land withdrawal area would be less than 2 hours (0.08 day). At this location the estimated equilibrium fraction would be 0.5, so the radon decay product activity would be 50 percent of the radon released, with these radionuclides available to enter the exposure pathways. For the population within 80 kilometers (50 miles), the estimated equilibrium fraction would be 0.6, and the radon decay product activity would be 60 percent of the radon released, with these radionuclides available to enter the exposure pathways. These estimates do not include removal mechanisms such as the deposition of radon decay products, so they are conservative, tending to overestimate the actual dose that could be received.

The screening dose factors for radon-222 and its decay products indicate that direct external radiation from radionuclides deposited on the ground would account for about 40 percent of the dose. Ingestion of the radon decay products in foodstuffs and inadvertently consumed soil would account for about 60 percent of the dose. Inhalation and external irradiation from radionuclides in the air would be minor exposure pathways. The analysis estimated the dose from radon-222 and its decay products by multiplying the radon-222 activity released by the equilibrium factor by the atmospheric dispersion factor at the exposure location by the radionuclide-specific dose factor, with appropriate unit conversions included. Table G-54 lists the screening dose factors for radon-222 and its decay products for members of the public. Results are presented in Chapter 4, Section 4.1.2.

Dose to members of the public (and to noninvolved workers, described below) is calculated in the following manner using the information presented throughout Section G.2:

$$\text{dose (millirem per year)} = Q \times \chi/Q \times F \times DF \times t \times \text{(unit conversion factors)}$$

where Q = activity released (curies per year)

χ/Q = atmospheric dispersion factor (seconds per cubic meter)

F = equilibrium fraction for radon decay products at exposure location (unitless)

DF = dose factor from Table G-54

t = exposure time, in hours per year

Unit conversion factors used include liters per cubic meter, picocuries per curies, and seconds per year. Multiplying the activity release by the atmospheric dispersion factor by the equilibrium fraction, if applicable—with appropriate unit conversions—yields the radionuclide concentration in air at the point of exposure.

G.2.4.2 Dose to Noninvolved Workers

The analysis used the same krypton-85 screening dose factor described above to calculate doses to noninvolved workers because the exposure pathway is simple (air submersion only) and is the same as for members of the public. However, the radon-222 screening dose factor for involved workers is different from that used for the public, because noninvolved workers are exposed only through the inhalation and plume exposure pathways. The other exposure pathways are not applicable for noninvolved workers, namely the ground exposure and ingestion pathways. The ground exposure pathway was not included because site workers would not typically be in locations where decay products could build up for many years without being physically disturbed or washed away.

Section G.2.1 describes the location of the maximally exposed noninvolved worker in the South Portal Development Area. There would be no releases from the South Portal during the other project phases and atmospheric dispersion factors would be much smaller (greater dispersion and, therefore, lower resulting radiation dose). The estimated equilibrium fraction for Yucca Mountain noninvolved worker exposure would be 0.22, the same as that for ventilation air at the exhaust point, as described in Section G.2.4.1. Transit times from release to a noninvolved worker or noninvolved worker population would be short, ranging from less than 1 minute to about 30 minutes at wind speeds of 3 meters per second (6.7 miles per hour), and deposition of radon decay products would occur, so the increase toward equilibrium would be small. The estimated equilibrium fraction for noninvolved workers at the Nevada Test Site would be 0.5, because the transit time of about 5 hours (0.19 day) for the 50-kilometer (31-mile) distance would allow the radon decay products to reach a higher level of equilibrium.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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Appendix H

Potential Repository Accident Scenarios: Analytical Methods and Results

APPENDIX H. POTENTIAL REPOSITORY ACCIDENT SCENARIOS: ANALYTICAL METHODS AND RESULTS

This appendix has been moved to Volume IV of this EIS.

Appendix I

Environmental Consequences of Long-Term Repository Performance

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APPENDIX I. ENVIRONMENTAL CONSEQUENCES OF LONG-TERM REPOSITORY PERFORMANCE

This appendix provides detailed supporting information on the calculation of the environmental consequences of long-term repository performance (postclosure, up to 1 million years). Chapter 5 summarizes these consequences for the Proposed Action, and Chapter 8, Section 8.3.1 summarizes the cumulative impacts of Inventory Modules 1 and 2.

Section I.1 introduces the bases for analysis of long-term performance. Section I.2 provides an overview of the use of computational models developed for the Total System Performance Assessment (TSPA) model, that was used for the analysis of long-term impacts to groundwater in this environmental impact statement (EIS). Section I.3 identifies and quantifies the inventory of waste constituents of concern for analysis of long-term performance. Section I.4 details the modeling extensions to the TSPA *nominal scenario* [Proposed Action inventory, reasonably maximally exposed individual (RMEI) location at approximately 18 kilometers, or 11 miles, downgradient of the potential repository, and no disruptive events other than seismic] developed to estimate potential impacts for expanded inventories. An estimate of how the impacts might change for locations beyond the RMEI location is also provided. Section I.5 provides detailed results for waterborne radioactive material impacts, while Section I.6 provides the same for waterborne chemically toxic material impacts. Section I.7 describes atmospheric radioactive material impacts. To aid readability, all the figures are placed at the end of the appendix.

HOW ARE THE TOTAL SYSTEM PERFORMANCE ASSESSMENT MODEL AND THIS EIS ANALYSIS RELATED?

The analysis of long-term performance for this EIS builds incrementally on the TSPA model.

This appendix is primarily concerned with those aspects of the EIS analysis of long-term performance that are incremental over the TSPA model. Only those parts of the analysis unique to this EIS are detailed in this appendix, and the text refers to the appropriate TSPA model documents for information on the bases of the analyses. Some aspects of the modeling detailed in the TSPA are repeated in this appendix in overview form to provide continuity and enhance understanding of the approach.

For a full understanding of all details of the analysis of long-term performance in this EIS, it is necessary to study not only this appendix but also the other TSPA model documents cited herein.

I.1 Introduction

This EIS analysis of postclosure impacts used and extended the modeling work performed for the Yucca Mountain site suitability evaluation that supports the site recommendation process. The EIS analysis relied on the GoldSim program computer simulation model (DIRS 151202-Golder Associates 2000, all) used by DOE to calculate radiological doses resulting from waterborne releases through the groundwater pathway.

Analysis of long-term performance for this EIS required several steps. The EIS analysis model started with the TSPA model, which was modified as discussed below. For this EIS the modeling (described in this appendix) was further expanded to evaluate the impacts for expanded waste inventories (see Section I.4). Additional calculations provided estimates of how the impacts would vary for two other distances [30 kilometers (19 miles) downgradient, and the discharge location that is 60 kilometers (37 miles) downgradient at Franklin Lake Playa (refer to Section I.4.5)], analysis of long-term groundwater impacts of chemically toxic materials, and estimates of atmospheric radiological doses to the local population.

The model used to evaluate long-term impacts of radioactive materials in the groundwater simulates the release and transport of radionuclides away from the repository into the unsaturated zone, through the unsaturated zone, and ultimately through the saturated zone to the accessible environment. Analysis of long-term performance depends greatly on the underlying process models necessary to provide thermal-hydrologic conditions, near-field geochemical conditions, unsaturated zone flow fields, and saturated zone flow fields as a function of time. Using these underlying process models involves multiple steps that must be performed sequentially before modeling of the overall system can begin.

Figure I-1 shows the general flow of information between data sources, process models, and the TSPA model. Several process-level computer models are identified in Figure I-1. Examples are the site- and drift-scale thermal hydrology model and the saturated zone flow and transport model. The process models are very large and complex computer software programs used in detailed studies to provide information to the TSPA model. These process models are generally where fundamental laboratory and field data are introduced into the modeling. The subsystem and abstracted models section of the figure encompasses those portions of the TSPA model that are modeled within the GoldSim program. Examples are the unsaturated zone flow fields and the biosphere dose conversion factors. These models are generally much simpler than the process models. They are constructed to represent the results of the more detailed process modeling studies. Often they are simple functions or tables of numbers. This is the process referred to as *abstraction*. It is necessary for some of these subsystem models to be quite complex, even extensive computer codes. The ultimate result sought from modeling long-term performance is a characterization of radiological dose to humans with respect to time, shown at the top of the TSPA section of the figure. This is accomplished by assessing behavior at intermediate points and “handing” off the results to the next subsystem in the primary release path.

ABSTRACTION

Abstraction is the distillation of the essential components of a process model into a suitable form for use in a TSPA. The distillation must retain the basic intrinsic form of the process model but does not usually require its original complexity. Model abstraction is usually necessary to maximize the use of limited computational resources while allowing a sufficient range of sensitivity and uncertainty analyses.

I.2 Total System Performance Assessment Methods and Models

DOE conducted analyses for this EIS to evaluate potential long-term impacts to human health from the release of radioactive materials from the Yucca Mountain Repository. The analyses were conducted in parallel with, but distinct from, the TSPA calculations for the site suitability evaluation. The methodologies and assumptions are detailed in the *Total System Performance Assessment for the Site Recommendation* (DIRS 153246-CRWMS M&O 2000, all), and the *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-CRWMS M&O 2001, all). These two versions of the model are referred to respectively here as the “Site Recommendation model” and the “Supplemental Science and Performance Analyses model.” Note that the Supplemental Science and Performance Analyses model starts with the Site Recommendation model and includes incremental enhancements to several parts of the Site Recommendation model. Further changes were made to the model to meet distinct requirements of this EIS. These changes are discussed in more detail in Section I.4 and in DIRS 157307-BSC (2001, Enclosure 1). In summary, the changes are as follows:

- The biosphere dose conversion factors are based on the Reasonably Maximally Exposed Individual (RMEI) defined in 40 CFR 197.21.

- The length of the saturated zone simulated in the performance-assessment model extends from the edge of the repository to where the principal flow path crosses north latitude 36 degrees 40 minutes 13.6661 seconds, as the point where the RMEI would reside. This location is approximately 2 kilometers (1.2 miles) north of the intersection of U.S. Route 95 and Nevada State Route 373, a location formerly known as “Lathrop Wells” and currently known as “Amargosa Valley,” that is approximately 20 kilometers (12 miles) downgradient from the repository.

- The groundwater protection standard using an annual water usage of 3.7 million cubic meters per year (exactly 3,000 acre-feet per year) was used in calculating the gross-alpha activity, the total radium concentration, and the total organ dose. All other concentrations were calculated using the same water usage as the Site Recommendation and the Supplemental Science and Performance Analyses models.

- The analysis used the waste inventory that was presented in *Inventory Abstraction* (DIRS 154841-BSC 2001, all). The difference between this inventory and that used in the Site Recommendation and Supplemental Science and Performance Analyses models is that for analysis purposes, U.S. Navy spent nuclear fuel is conservatively modeled as commercial spent nuclear fuel (DIRS 152059-BSC 2001, all and DIRS 153849-DOE 2001, Section 4.2.6.3.9, p. 4-257) and not as DOE-owned spent nuclear fuel.

- Waste package corrosion for the calculations in this report was due to general corrosion independent of temperature.

- The process-level lower-temperature repository operating mode thermal-hydrologic results were corrected to include radiation heat transfer.

- The model was expanded to accommodate inventories other than that for the Proposed Action.

The TSPA is a comprehensive systems analysis in which models of appropriate levels of complexity represent all important features, events, and processes to predict the behavior of the system being analyzed and to compare this behavior to specified performance standards. In the case of the proposed Yucca Mountain Repository system, a TSPA must capture all of the important components of both the engineered and the natural barriers. In addition, the Yucca Mountain TSPA must evaluate the overall uncertainty in the prediction of waste containment and isolation, and the risks caused by the uncertainty in the individual component models and corresponding parameters.

The components of the Yucca Mountain Repository system include five major elements that the TSPA must evaluate for the nominal scenario:

- The natural environment unperturbed by the presence of underground openings or emplaced wastes

- Perturbations to the natural system caused by construction of the underground facilities, waste emplacement, and expected natural events (such as seismic behavior)

- The long-term degradation of the engineered components designed to contain the radioactive wastes

- The release of the radionuclides from the engineered containment system

- The migration of these radionuclides through the engineered and natural barriers to the biosphere and their potential uptake by people, leading to a radiation dose consequence

The analysis included models associated with such disruptive events as volcanism and human intrusion (drilling). Sections I.2.10 and I.2.11 provide an overview of the processes and the models used to represent these disruptive events.

The EIS analysis of long-term performance represents a "snapshot in time," and ongoing work will help refine that snapshot. In the meantime, DOE believes the results of this EIS analysis are conservative estimates, and that work currently in progress or planned will increase confidence in the overall modeling approach.

The calculations for the TSPA model and calculations for this EIS were performed within a probabilistic framework combining the most likely ranges of behavior for the various component models, processes, and related parameters. In some cases, bounding conservative values were used where the available data did not support development of a realistic range. This appendix presents the results as time histories of annual radiological dose to an individual over 10,000 and 1 million years following repository closure. As noted above, the TSPA model implements some of the individual process models directly, while other process models run outside the TSPA model to produce *abstractions* in the form of data tables, response surfaces, or unit-response functions. The TSPA model provides a framework for incorporating these abstractions and integrating them with other subsystem models. This is done in a *Monte Carlo* simulation-based methodology to create multiple random combinations of the likely ranges of the parameter values related to the process models. Probabilistic performance of the entire waste-disposal system was computed in terms of radiological dose to individuals at selected distances from the repository.

MONTE CARLO METHOD: UNCERTAINTY

An analytical method that uses random sampling of parameter values available for input into numerical models as a means of approximating the uncertainty in the process being modeled. A Monte Carlo simulation comprises many individual runs of the complete calculation using different values for the parameters of interest as sampled from a probability distribution. A different outcome for each individual calculation and each individual run of the calculation is called a *realization* (DIRS 153246-CRWMS M&O 2000, p. A-55).

The methodology for analysis of long-term performance for this EIS draws on the extensive analyses performed in support of the TSPA model. Most of the process models (and their abstractions) developed for the TSPA model were used directly in the analyses described in this appendix. Components that were modified to account for the additional analyses considered in this EIS are emphasized in this appendix. However, for continuity, the sections that follow include a general overview of all the elements of the TSPA model.

I.2.1 FEATURES, EVENTS, AND PROCESSES

The first step in the TSPA is to decide which representations of possible future states of the proposed repository (scenario classes and scenarios) are sufficiently important to warrant quantitative analysis. The TSPA model can analyze only a relatively small number of the essentially infinite combinations of features, events, and processes that could affect the system. It is important, therefore, that the scenarios chosen for analysis provide a sound basis for evaluating the performance of the repository. Specifically, the chosen scenarios must be representative of the conditions of greatest relevance to forecasting the long-term behavior of the system.

The first step in developing scenarios is to make an exhaustive list of features, events, and processes that could apply to the repository system. The initial list is developed using a number of resources:

- Lists previously compiled by other organizations on an international scale (such as the Nuclear Energy Agency of the Organization for Economic Cooperation and Development)
- Lists compiled during earlier stages of site exploration
- Lists developed by experts from the Yucca Mountain Project and outside consultants

FEATURES, EVENTS, AND PROCESSES

Features are physical parts of the system important to how the system could perform. Examples include the Ghost Dance Fault and the Topopah Spring stratigraphic unit.

Events are occurrences in time that can affect the performance or behavior of the system. Events tend to happen in short periods in comparison to the period of concern, and they tend to occur at unpredictable times. Examples include a volcanic intrusion or a human intrusion by drilling.

Processes are physical and chemical changes that occur over long periods, tend to be 100-percent likely to occur, and are predictable. Examples include corrosion of the metals in the waste package and dissolution of waste form materials after exposure to water.

The starting list is subjected to a comprehensive screening process. Features, events, and processes are screened from the list based on several criteria:

- Obvious inapplicability to the specific site (for example, the starting list included processes that occur only in salt, a rock type known to be not present at Yucca Mountain).
- Very low probability of occurrence (for example, meteorite impact)
- Very low consequence to the closed repository (for example, an airplane crash)
- Exclusion by regulatory direction (for example, deliberate human intrusion)

The remaining features, events, and processes are combined in scenarios that incorporate sequences of events and processes in the presence of features. The three main scenarios evaluated are:

- Nominal scenario (generally undisturbed performance with only seismic events)
- Volcanism scenario (eruption through the repository or intrusion of igneous material into the repository)
- Inadvertent human intrusion scenario.

When the scenarios described above were formed from the Features, Events, and Processes retained after screening, the focus was on the 10,000-year compliance period. Therefore in the screening documentation the reliance on a limit of 10,000-years was sometimes expressed. This EIS is charged by 40 CFR Part 197 with the task of reporting the peak dose values whenever they occur during the period of geologic stability. As can be seen by the results in this EIS, the peaks occur at times considerably longer than 10,000 years and it was necessary to carry out the analysis for 1 million years in order to establish the peak dose. Because the TSPA model used to generate all the results in the EIS is the same model that resulted from the Features, Events, and Processes screening it is important to explore the possible effect of the use of a 10,000 limit when screening Features, Events, and Processes. The following discussions are provided by the Features, Events, and Processes screening staff for that purpose (DIRS 155937-Freeze 2001, all). In addition to the discussions from the DIRS 155937-Freeze (2001, all) document there is also a short discussion of seismic Features, Events, and Processes. For a comprehensive discussion of all the Features, Events, and Processes the reader is referred to the Features, Events, and Processes database documentation (DIRS 154365-Freeze, Brodsky, and Swift 2001, all).

Note that in numbers given in the headings or text of Sections I.2.1.1 through I.2.1.7 (in the form "FEP No. X.X.X.X.X") refer to an index number from the Features, Events, and Processes database (DIRS 154365-Freeze, Brodsky, and Swift 2001, all).

I.2.1.1 Tectonic Activity (FEP No. 1.2.01.01.00)

The current strain rate is indicated by DIRS 118952-Savage, Svarc, and Prescott (1999, p. 17627) as less than 2 millimeters per year (0.08 inch per year) and is reflected in local slip rates of between 0.001 and 0.03 millimeters per year (0.0004 and 0.001 inches per year). At the highest rate, the total slip after 10,000 years would be on the order of 0.010 to 0.3 meters (0.03 to 1 foot), but after 1 million years could be on the order of 1 to 30 meters (3.3 to 98 feet). The increased rates of tectonic and igneous activity in the geologic past (and leading to the 30-meter value) were associated with greater crustal strain rates than exist currently. In particular, DIRS 118942-Fridrich (1999, all) indicate extension of the Crater Flat structural basin to have been on the order of 18 to 40 percent between about 12.6 and 11.6 million years ago during the major pulse of extension, with the rate of extension declining exponentially since 11.6 million years ago. From the late Quaternary through the present, the rate of extension is less than 1 percent of the initial rate. These studies suggest that crustal extension rates are likely to vary insignificantly or to decrease with time. As a consequence, assumption of the existing tectonic setting and strain rates for periods out to 1 million years, for purposes of the EIS, is reasonable, although quantification of associated displacements would exhibit a time-dependent increase in uncertainty.

The median probability for exceeding fault displacements greater than 3 meters (10 feet) on the Solitario Canyon Fault is approximately 0.0001 in 10,000 years, and the median and mean probability for fault displacement on intrablock faults of 2 meters (6.6 feet) or greater is less than 0.0001 in 10,000 years (DIRS 100354-USGS 1998, all). The projected values assume that the tectonic strain rate is either equal to or less than the existing strain rate. Projection and use of these displacements for a 1-million-year time frame is appropriate, but is accompanied with an increase in uncertainty in the probable displacement value.

Based on the repository design, the drifts could accommodate as much as 2 meters (6.6 feet) of vertical displacement on intrablock faults before waste package shearing conditions could occur and, with the use of set-backs, at least 3 meters (10 feet) of offset could be accommodated in the Solitario Canyon Fault, and possibly more if distributed faulting is considered. Hypothetical models at the mountain-scale also suggest that flow in fault zones and fractures would not be significantly affected by displacement of as much as 10 meters (33 feet). The tolerance values are not time-dependent. The projected total slip values at 1 million years (1 to 30 meters, or 3.3 to 98 feet) are of the same order of magnitude as the tolerance limit (1 to 10 meters, or 3.3 to 33 feet).

Because the tolerance values are the same order of magnitude as the projected total slip, and because the tectonic setting and history of the site suggest that strain rates will either vary insignificantly or decrease, the assumptions and models in the TSPA related to tectonic activity should be reasonable and applicable for the 1-million-year time span as well.

I.2.1.2 Erosion/Denudation (FEP No. 1.2.07.01.00)

Erosion is a process that is expected to be ongoing at Yucca Mountain. The maximum erosion over 10,000 years is expected to be less than 10 centimeters (3.9 inches) (DIRS 100520-YMP 1993, p. 55), which is within the range of existing surface irregularities.

After 1 million years the maximum total erosion would be 10 meters (33 feet), assuming the erosion rate estimated for the next 10,000 years remained constant for the next 1 million years. This maximum value is far less than the amount required to expose waste at the land surface, and possible effects would therefore be limited to changes in infiltration and flow in the unsaturated zone. Local changes of as much as 10 meters would represent a small change relative to the hundreds of meters (thousands of feet) of topographic variability already incorporated in the infiltration model used to calculate flow in the unsaturated zone. The effects of erosion on infiltration are therefore considered negligible. Erosion due to normal surface processes at Yucca Mountain is therefore excluded from the 1 million-year analyses.

Future climate projections extending to 10,000 years (DIRS 136368-USGS 2000, all; DIRS 153038-CRWMS 2000, all) indicate that, although the climate is expected to evolve to a cooler, wetter climate, conditions will be that of a glacial transition or glacial-type climate. As a result, direct glacial erosion and transport is not considered a credible event. Therefore, glacial erosion is excluded on the basis of low probability.

The effects of erosion processes on how radionuclides might accumulate in soils and subsequently enter the biosphere are included (DIRS 136281-CRWMS M&O 2000, Section 6.1.1) for the post-10,000-year period. The effects of erosional processes in the biosphere are considered in an Analysis Model Report titled *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (DIRS 136281-CRWMS M&O 2000, all) and are considered in *Total System Performance Assessment for the Site Recommendation* (DIRS 153246-CRWMS M&O 2000, Sections 3.9 and 3.10) as part of the peak dose calculations.

I.2.1.3 Periglacial Effects (FEP No. 1.3.04.00.00)

This process refers to climate conditions that could produce a cold, but glacier-free, environment. Results of such a climate could include permafrost (permanently frozen ground). Some consequences of such a condition identified in the secondary Features, Events, and Processes are enhanced erosion due to the freeze/thaw cycle and the trapping of gases in or near the proposed repository.

Global climate change was addressed in the TSPA using a climate model based on paleoclimate information. That is, the record of climate changes in the past was used to predict changes in climate for the future. Because the geologic record indicates that climatic conditions during the Quaternary period (the past 1.6 million years) at no time resulted in plant communities at Yucca Mountain that are consistent with periglacial conditions (DIRS 136281-CRWMS M&O 2000, Section 4.2.4), this process has been excluded on the basis of low probability.

Future climates are described in terms of discrete climate states that are used to approximate continuous variations in climate. The effects of seasonality are included in the climate model by using climate analogs with specific seasonal meteorological records. More specific information about the methods used to predict future climate change and the findings for the climate model is provided in DIRS 136368-USGS (2000, Section 6). Climate modeling is incorporated in the TSPA through the unsaturated zone flow fields, which have different surface-water infiltration as a result of different climates. A description of the modeling methods used for infiltration and how infiltration is affected by climate is in DIRS 136368-USGS (2000, Section 6).

Potential future climate conditions at Yucca Mountain were analyzed in two Analysis Model Reports: *Future Climate Analyses* (DIRS 136368-USGS 2000, all) and *Documentation of Million-Year TSPA* (DIRS 153038-CRWMS 2000, all). The climate at Yucca Mountain for the next 10,000 years is treated as a sequence of three climate states: modern (interglacial) climate for 400 to 600 years, monsoon climate for 900 to 1,400 years, and glacial-transition (intermediate) climate for the balance of the 10,000-year period. The glacial-transition (intermediate) climate occurs either preceding or following the colder, wetter full glacial climate states. Three additional full-glacial climate states are specified during the longer period of 1 million years, with different climate stages synchronized with the earth orbital clock. Full-glacial stages would encompass about 21 percent of the time over the next 1 million years. The intermediate climate would be the dominant climate for the next 1 million years.

I.2.1.4 Glacial and Ice Sheet Effects (FEP No. 1.3.05.00.00)

This process refers to the local effects of glaciers and ice sheets. Paleoclimate records indicate that glaciers and ice sheets have not occurred at Yucca Mountain at any time in the past (DIRS 136368-USGS 2000, Section 6.2). The closest alpine glaciers to Yucca Mountain during the Pleistocene were in the Sierra Nevada of California and possibly the Spring Mountains in Nevada (DIRS 151945-CRWMS M&O 2000, Section 4.2.3.3.6), too far from Yucca Mountain to have any effect on site geomorphology or hydrology. Given the relatively low elevation of Yucca Mountain, there is no credible mechanism by which a glacier could form at the site over the next 10,000 years, and there is no evidence to suggest formation at Yucca Mountain in the next 1 million years. Therefore, this process is excluded on the basis of low probability. Note, however, that the regional climatic effects of ice sheets that might form farther north are included based on a change in climate states.

I.2.1.5 Hydrostatic Pressure on Container (FEP No. 2.1.07.04.00)

A repository at Yucca Mountain would emplace waste above the water table in a fractured, porous medium. Thus, the pressure on the waste package is approximately atmospheric under present conditions. Possible changes in the elevation of the water table due to climate change and tectonic processes have been evaluated (DIRS 153931-CRWMS M&O 2001, Sections 6.2.11 and 6.2.8; DIRS 154826-BSC 2001, Section 6.7.6), and water table fluctuations due to climate change are included in the TSPA model. Even under the wettest future climate states, however, the highest elevation of the water table would be far below the emplacement drifts, and hydrostatic pressure effects on the packages are therefore excluded on the basis of low probability for both 10,000-year and 1-million-year analyses.

I.2.1.6 Soil and Sediment Transport (FEP No. 2.3.02.03.00)

Transport of soil and sediments in the biosphere is discussed in the Analysis Model Reports titled *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (DIRS 136281-CRWMS M&O 2000, all) and *Nominal Performance Biosphere Dose Conversion Factor Analysis* (DIRS 152539-CRWMS M&O 2001, all). The results of these analyses are used in Sections 3.9 and 3.10 of the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000). Aeolian and fluvial transport of contaminated volcanic ash has been indirectly included in the TSPA–Site Recommendation igneous disruption scenario through the use of a wind direction fixed toward the critical group for all hypothetical eruptions. As described in Section 3.10 of TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000), use of a fixed wind direction compensates for the lack of an explicit model for sediment transport following ash deposition by ensuring that all eruptions would result in the deposition of contaminated ash at the location of the critical group, regardless of the wind direction at the time of the event. The TSPA–Site Recommendation calculations include the probability of eruptive events extending past the 10,000-year regulatory period to calculate peak dose.

Paleoclimate records indicate that glaciers and ice sheets have not occurred at Yucca Mountain at any time in the past (DIRS 136368-USGS 2000, Section 6.2). The closest alpine glaciers to Yucca Mountain during the Pleistocene were in the Sierra Nevada of California and possibly the Spring Mountains in Nevada (DIRS 151945-CRWMS M&O 2000, Section 4.2.3.3.6), too far from Yucca Mountain to have any effect on site geomorphology or hydrology. Given the relatively low elevation of Yucca Mountain, there is no credible mechanism by which a glacier could form at the site within the time frames considered. Therefore, glacial transport of soil and sediments is not considered credible and this process is excluded on the basis of low probability.

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I.2.1.7 Seismic Damage to Waste Packages

This discussion refers to the following Features, Events, and Processes:

- Seismic vibration causes container failure (FEP No. 1.2.03.02.00)
- Mechanical impact on waste container and drip shield (FEP No. 2.1.03.07.00)
- Effects and degradation of drip shield (FEP No. 2.1.06.06.00)
- Rockfall – large block (FEP No. 2.1.07.01.00)
- Mechanical degradation or collapse of drift (FEP No. 2.1.07.02.00)

These events all have to do with possible damage to the waste packages or drip shields either directly or indirectly (for example, rock fall) due to seismic events. In the Features, Events, and Processes screening these events were screened out for low consequence because up to 10,000 years the waste packages remain essentially intact (see detailed results in Section I.5) and possess their original design strength. Because the packages are designed to withstand seismic events that are of sufficient likelihood during the 10,000-year period, it follows that a low-consequence screening for the 10,000-year period is justified.

The analysis for the million-year period extended the screening of seismic damage to waste packages throughout that time. This was an analytical assumption based on using the best data and models available for the Final EIS. No quantitative analysis was performed to determine when a waste package might degrade to the point where it could be damaged by a seismic event. However, it is reasonable to expect that peak dose estimates would likely have been higher (by an unknown amount) if the analysis accounted for potential seismic damage of degraded waste packages hundreds of thousands of years into the future.

I.2.2 UNSATURATED ZONE FLOW

Changes in climate over time provide a range of conditions that determine how much water could fall onto and infiltrate the ground surface. Based on current scientific understanding, the current climate is estimated to be the driest that the Yucca Mountain vicinity will ever experience. All future climates were assumed similar to current conditions or wetter than current conditions. The *climate* model provides a forecast of future climates based on information about past patterns of climates (DIRS 153246-CRWMS M&O 2000, p. 3-38 to 3-42). This is generally accepted as a valid approach because climate is known to be cyclical and largely dependent on repeating patterns of earth orbit and spin. The model represents future climate shifts as a series of instant changes. During the first 10,000 years, there are three changes, in order of increasing wetness, from present-day to a monsoon and then to a glacial-transition climate. Between 10,000 years and 1 million years there are 45 changes between six climate states incorporated in the TSPA model (DIRS 153246-CRWMS M&O 2000, p. 3-38):

CLIMATE CHANGE

The analysis of long-term performance considered six climate states. Many changes in climate states occur in the simulation over a 1-million-year period after closure. The times of change are keyed to known past cycles for the previous million years as determined by paleoclimatology studies. (DIRS 153246-CRWMS M&O 2000, Figure 3.2-16, p. F3-24).

- Interglacial Climate (same as present day)
- Intermediate Climate (same as the Glacial-transition)
- Intermediate/Monsoon Climate
- Three stages of Glacial Climate of varying infiltration rates

Precipitation that is not returned to the atmosphere by evaporation or transpiration enters the unsaturated zone flow system. Water infiltration is affected by a number of factors related to climate, such as an increase or decrease in vegetation on the ground surface, total precipitation, air temperature, and runoff. The *infiltration* model uses data collected from studies of surface infiltration in the Yucca Mountain region (DIRS 155950-BSC 2001, Section 3.2.2). It treats infiltration as variable in the region, with more occurring along the crest of Yucca Mountain than along its base. The results of the climate model affect assumed infiltration rates. For each climate, there is a set of three infiltration rates (high, medium, low) and associated probabilities. This forms a discrete distribution that is sampled in the probabilistic modeling. The sampled ranges are described in Tables I-1 and I-2. Whenever a particular climate state is in effect, the associated infiltration rate distribution is sampled for each realization of the simulation.

Table I-1. Average net infiltration rates (millimeters per year) over the unsaturated zone flow and transport model domain for the present-day, monsoon, and glacial transition climate states.[a,b]

Climate	Lower bound	Mean	Upper bound
Present day	1.3	4.6	11.1
Monsoon	4.6	12.2	19.8
Glacial transition	2.5	17.8	33.0

a. Adapted from DIRS 155950-BSC (2001, Table 3.3.2-1).
b. To convert from millimeter per year to inch per year, multiply by 0.03937.

Table I-2. Average net infiltration rates (millimeters per year) over the unsaturated zone flow and transport model domain for full-glacial climate states.[a,b]

Climate	Lower bound	Mean	Upper bound
Glacial, Stage 8/10	33.0[c] (36.0[d])	87.9	151.0
Glacial, Stage 6/16	24.4	87.9	151.0
Glacial, Stage 4	12.9	24.4	87.9

a. Adapted from DIRS 155950-BSC (2001, Table 3.3.2-3).
b. To convert from millimeter per year to inch per year, multiply by 0.03937.
c. Derived using upper-bound intermediate climate meteorological station data (DIRS 155950-BSC 2001, Tables 3.3.1-5, 3.3.1-6).
d. Derived using alternate Stage 6/16 meteorological station data (DIRS 155950-BSC 2001, Tables 3.3.1-5, 3.3.1-6).

Water generally moves downward in the rock matrix and in rock fractures. The rock mass at Yucca Mountain is composed of volcanic rock that is fractured to varying degrees because of contraction during cooling of the original, nearly molten rock and because of extensive faulting in the area. Water flowing in the fractures moves much more rapidly than water moving through the matrix. At some locations, water might collect in locally saturated zones (*perched water*) or might be laterally diverted because of differing rock properties at rock layer interfaces. The overall unsaturated flow system is heterogeneous, and the locations of flow paths, velocities, and volumes of groundwater flowing along these paths are likely to change many times over the life of the repository system. The *mountain-scale unsaturated zone flow* model assumes constant flow over a specific period (taken from the infiltration model) and generates three-dimensional flow fields for three different infiltration boundary conditions, the six different climates described above, and several values of rock properties (DIRS 153246-CRWMS M&O 2000, pp. 3-29 and 3-41). The model is an isothermal model; thermal effects can be neglected because flow would be strongly perturbed only by heat near the emplacement drifts and at early times (DIRS 153246-CRWMS M&O 2000, p. 3-31). The influence of heat near the drifts is dealt with in the thermal hydrology models discussed below. The flow fields from the mountain-scale unsaturated zone flow model are the abstractions that are utilized by the TSPA model while the system model is running. The TSPA model simply switches to the correct flow field for the sampled infiltration rate, as dictated by the current climate state and sampling of the infiltration rate range.

After water returns to the repository walls, it would drip into the repository. The number of seeps that would occur and the amount of water that would be available to drip would be restricted by the low rate at which water flows through Yucca Mountain, which is in a semiarid area. Drips would occur only if the hydrologic properties of the rock mass caused the water to concentrate enough to feed a seep. Over time, the number and locations of seeps would increase or decrease, corresponding to increased or decreased infiltration based on changing climate conditions. The *seepage flow* model calculates the amount of seepage that could occur based on input from the unsaturated zone flow model (DIRS 155950-BSC 2001, Section 4.3). The basic conceptual model for seepage suggests that openings in unsaturated rock act as capillary barriers and divert water around them. For seepage to occur in the conceptual model, the rock pores at the drift wall would have to be locally saturated. Drift walls could become locally saturated by either disturbance to the flow field caused by the drift opening or variability in the permeability field that created channeled flow and local ponding. Of the two reasons, the variability effect is more important. Drift-scale flow calculations made with uniform hydrologic properties suggest that seepage would not occur at expected percolation fluxes. However, calculations that include permeability variations do estimate seepage, with the amount depending on the hydrologic properties and the incoming percolation flux. The seepage abstraction is based on extensive modeling calibrated by measurements from onsite testing in the Exploratory Studies Facility (DIRS 153246-CRWMS M&O 2000, pp. 3-35 to 3-36, and DIRS 155950-BSC 2001, Section 4.3.1.5). The seepage abstraction includes probability distributions for the fraction of waste packages encountering seepage and the seep flow rate, accounting for parameter uncertainty, spatial variability, and other effects, such as focusing (DIRS 155950-BSC 2001, Section 4.3.2), episodicity (DIRS 155950-BSC 2001, Section 4.3.5), rock bolts (DIRS 155950-BSC 2001, Section 4.3.3), drift degradation (DIRS 155950-BSC 2001, Section 4.3.4) and coupled processes (DIRS 155950-BSC 2001, Sections 4.3.5 through 4.3.7). All of these parameters are input as uncertainty distributions that are sampled in the probabilistic modeling.

I.2.3 ENGINEERED BARRIER SYSTEM ENVIRONMENTS

Engineered barrier system environments refer to the thermodynamic and chemical environments in the emplacement drifts. These environments control processes that affect the components of the engineered barrier system (such as the drip shields, waste packages, and waste forms). The environmental characteristics of importance are the degradation of the drift (including rock fall into the drift), temperature, relative humidity, liquid saturation, pH, liquid composition, and gas composition. Thermal effects on flow and chemistry outside the drifts are also important because they affect the amount and composition of water and gas entering the drifts. The engineered barrier system environments are important to long-term repository performance because they would help determine degradation rates of components, quantities and species of mobilized radionuclides, transport of radionuclides through the drift into the unsaturated zone, and movement of fluids into the unsaturated zone.

The *drift degradation model* describes the deterioration of the rock mass surrounding the repository emplacement drifts. Deterioration would occur by failure of fractures that bound blocks of rock at the drift walls and the resultant falling of those blocks into the drift. The deterioration is described in terms of key block analysis (DIRS 153246-CRWMS M&O 2000, pp. 3-43), which is a tool used for the following purposes:

- Provide a statistical description of block sizes formed by fractures around the emplacement drifts
- Estimate changes in drift profiles due to fallen blocks of rock
- Provide an estimate of the time required for significant drift deterioration to occur.

Key blocks would be formed by the intersection of three or more fracture planes with the excavation. Key blocks could become dislodged and fall because of seismic effects. A detailed analysis, based on observation and testing, was used to develop an abstraction of block failures and rockfalls. The abstraction is in the form of tables of numbers and volumes of blocks falling per unit length of emplacement drift as a function of time due to seismic and other effects.

Within the TSPA model, most engineered system calculations were performed for a limited number of waste package locations. In the model, each of these locations is representative of a group of waste packages with similar environmental characteristics. Radionuclide releases, for example, were calculated for a representative waste package and then scaled up by the number of failed waste packages in the group. Not all waste packages in a group would fail at the same time because additional variability is included in the waste package degradation calculation. The waste package groups (referred to as *bins*) are not based on physical location. Rather, the bins are based on infiltration patterns (that is, divided into categories of specific ranges of infiltration rate) and on waste type (that is, codisposal packages and commercial spent nuclear fuel packages) (DIRS 153246-CRWMS M&O 2000, Section 3.3.2).

The heat generated by the decay of nuclear materials in the repository would cause the temperature of the surrounding rock and waste packages to rise from the time of emplacement until a few hundred years after repository closure (DIRS 153246-CRWMS M&O 2000, Figure 3.3-9, p. F3-33). The water and gas in the heated rock would be driven away from the repository during this period, referred to in this EIS as the *thermal pulse*. The thermal output of the materials would decrease with time; eventually, the rock would return to its original temperature, and the water and gas would flow back toward the repository. The *multi-scale thermal hydrology model* is used to study the processes that would govern the temperature, relative humidity, liquid saturation, liquid flow rate, liquid evaporation rate, and thermal effects on seepage. Drift-scale modeling includes coupling of drift-scale processes with mountain-scale processes to account for effects such as faster cooling of waste packages near the edge of the repository, as compared to waste packages near the center. A multi-scale modeling and abstraction method was developed to couple drift-scale processes with mountain-scale processes (DIRS 153246-CRWMS M&O 2000, pp. 3-56 to 3-58, and DIRS 155950-BSC 2001, Section 5.3.1). In addition, a coupled *thermal-hydrology-chemistry model* was developed to study the coupled effects on the heat, flow and chemistry of the system (DIRS 153246-CRWMS M&O 2000, p. F3-33). The results of these detailed modeling studies are abstracted as response surfaces of temperature, humidity, and liquid saturation.

The source term for transport of radionuclides from the proposed repository in the unsaturated zone and saturated zone water flow is the radionuclide flux from inside the drifts to the unsaturated zone rock. That flux would be influenced by the in-drift engineered barrier system chemical environment. The *engineered barrier system geochemical environment models* (DIRS 153246-CRWMS M&O 2000, pp. 3-62 to 3-69 and DIRS 155950-BSC 2001, Sections 6.3.1 and 6.3.3) were used to study the changing composition of gas, water, colloids, and solids in the emplacement drifts under the perturbed conditions of the repository. Several submodels were integrated to provide detailed results and interpretations. The major composition changes would be caused by the thermal loading of the system and the emplacement of large masses of materials that can react with water and gas in the system. The system would continually change due to the heating and cooling cycle. Because the emplaced materials would be very different from the host rock, the entering water and gas would be altered by reaction with these materials. Emplaced materials could be an additional source of colloids that could affect how radionuclides were transported in the aqueous system. The engineered barrier system geochemical environment models produce detailed results that are then abstracted for the following processes:

- Water and cement interactions
- Gas and water interactions
- Evaporation of water and condensation of vapor
- Salts precipitation and dissolution
- Microbial activity and effects
- Corrosion and degradation of engineered barrier system components

- Water and invert interactions
- Water and colloids interactions.

The abstractions were integrated into the TSPA model as chemistry lookup tables for various periods, parametric results, and sometimes enhancement or correction factors for other processes such as corrosion or transport (DIRS 153246-CRWMS M&O 2000, pp. 3-69 to 3-79 and DIRS 155950-BSC 2001, Sections 5.3.2.2 and 6.3.1.6).

The location of the seeps would depend to some extent on the natural conditions of the rock but also on the alterations caused by the construction of a repository. Alterations, such as increased fracturing, would be caused by mechanical processes related to drilling the drifts or by thermal heating and expansion of the drift walls. The alterations in the seepage could also be caused by chemical alterations occurring as the engineered materials dissolved in water and reprecipitated in the surrounding rock, closing the pores and fractures. The chemistry in the drift would change continually because of the complex interactions between the incoming water, circulating gas, and materials in the drift (for example, concrete from the liner or metals in the waste package). The changes in chemistry would be strongly influenced by heat during the thermal pulse.

The seepage would flow through the engineered barrier system along eight pathways. These pathways are (DIRS 155950-BSC 2001, Sections 8.2 and 8.3):

1. Seepage flux entering the drift—This would be the liquid flow into the engineered barrier system.

2. Flow through the drip shield—Liquid flux through the drip shield would begin after holes formed due to general corrosion.

3. Diversion around the drip shield—The portion of the flux that did not flow through the drip shield was assumed to bypass the invert and flow directly into the unsaturated zone.

4. Flow through the waste package—The fluid flow through the waste package would be based on the presence of holes due to general corrosion. The liquid flux through any holes in the waste package is calculated using a flux splitting algorithm that incorporates the fraction of the waste package or drip shield that has openings. This algorithm considers the projected patch area on a breached waste package or drip shield.

5. Flow diversion around the waste package—The portion of the flux that did not flow through the drip shield and onto the waste package was assumed to bypass the waste form and flow directly onto the invert.

6. Evaporation from the invert condensation underneath the drip shield—The magnitude of the evaporative flux from the invert would be based on the thermal-hydrologic abstraction.

7. Flow from the waste package to the invert—All flux from the waste package would flow to the invert, independent of breach location on the waste package. The presence of the emplacement pallet was ignored, and the waste package was assumed to be lying on the invert so a continuous liquid pathway for diffusive transport would exist at all times.

8. Flow through the invert into the unsaturated zone—Flow could be by advection or diffusion. The model accounts for sorption in the invert.

The model accounts for the evaporation of some of the liquid flux to the drip shield (DIRS 155950-BSC 2001, Section 8.3.1.3). The evaporation rate at the top of the drip shield would be bounded by the amount of heat available to vaporize water on the upper portion of the drip shield. This heat flow rate into the upper portion of the drip shield was used to determine the maximum volumetric flow rate of incoming seepage water that could be completely vaporized at this location.

I.2.4 WASTE PACKAGE AND DRIP SHIELD DEGRADATION

The radioactive waste placed in the proposed repository would be enclosed in a two-layer waste package. The layers would be of two different materials that would fail at different rates and from different mechanisms as they were exposed to various repository conditions. The outer layer would be a high-nickel alloy metal (Alloy-22) and the inner layer a stainless-steel alloy metal (316NG). To divert dripping water away from the waste package and thereby extend waste package life, a Titanium Grade 7 drip shield would be placed over the waste packages just prior to repository closure. The drip shield would divert water entering the drift from above preventing seep water from contacting the waste package. The *drip shield and waste package degradation models* were used to simulate the degradation of these components (DIRS 153246-CRWMS M&O 2000, pp. 3-79 to 3-91, DIRS 155950-BSC 2001, Section 7, and DIRS 157307-BSC 2001, Enclosure 1). Three main types of degradation were considered in the nominal scenario: humid-air general corrosion, aqueous general corrosion, and stress corrosion cracking. Two additional corrosion processes—microbially induced corrosion and thermal aging/phase instability—were considered to provide enhanced general corrosion on the waste package. General corrosion mechanisms would be conceptually similar for the drip shield and waste package, and were simulated using a common approach. Mechanical failure by rockfall was screened out of the model due to low consequence.

The primary models supplying input to the drip shield and waste package degradation abstractions are the thermal hydrology model and the in-drift geochemical abstraction model. Output from the degradation models is a time-dependent quantitative assessment of the drip shield and waste package degradation and failure. Results include the time to initial breach for the drip shield and the waste package; time to first breach of the waste package by stress corrosion crack failure; and the degree of drip shield and waste package failure as a function of time. The time of the first breach of the waste package would correspond to the start of waste form degradation in the breached package. The output also includes the uncertainty and spatial variation of the degradation information for each waste package and drip shield at different locations (described above as *bins*) within the potential repository. A recent reevaluation of potential early waste package failure mechanisms indicated that improper heat treatment of waste packages could lead to a gross failure of affected waste packages, although the probability of this occurrence is very low. Therefore, improper heat treatment of waste packages is now modeled in the current waste package degradation analysis (DIRS 155950-BSC 2001, Section 7.3.6). An analysis of manufacturing and testing led to a probability distribution for the number of packages that could fail from improper heat treatment of the Alloy-22 closure weld. The resulting distribution is listed in Table I-3. The distribution for waste package failures reflects a very conservative view, because it is assumed that if the outer weld was not properly heat treated the package would automatically fail, even though improper heat treatment would not necessarily result in failure, and the inner weld on the Alloy-22 and the inner stainless steel weld would probably remain intact. This distribution was sampled for each realization of the TSPA model and resulted in early failures of a very small number of waste packages in some of the realizations. This would result in very small releases during the first 10,000 years after closure.

The analysis in this EIS assessed the possible effects of waterborne chemically toxic materials. The analysis did not identify any organic materials as being present in sufficient quantities to be toxic. A screening process eliminated most other materials because they were not of concern for human health effects (see Section I.6.1). Some of the components of the high-nickel alloy (such as chromium, molybdenum, nickel, and vanadium) would be of sufficient quantity and possible toxicity to warrant

Table I-3. Poisson probabilities for improper heat treatment of waste packages.[a]

Number of packages	Proposed Action		Inventory Module 1		Inventory Module 2	
	Probability	Cumulative probability	Probability	Cumulative probability	Probability	Cumulative probability
0	0.76874	0.76874	0.69011	0.69011	0.98669	0.98669
1	0.20218	0.97092	0.25596	0.94608	0.013224	0.999911
2	0.026587	0.99751	0.047468	0.99354	8.8615×10^{-5}	0.9999996
3	2.3308×10^{-3}	0.99984	5.8687×10^{-3}	0.99941	3.9588×10^{-7}	1
4	1.5325×10^{-4}	0.999992	5.4417×10^{-4}	0.999957	1.32464×10^{-9}	1
5	8.0608×10^{-6}	1	4.0367×10^{-5}	0.9999974	3.5555×10^{-12}	1

a. Calculated from the mean Poisson value entered in the performance model.

further analysis. The rate of release of these materials was taken directly from data used for the waste package degradation modeling.

I.2.5 WASTE FORM DEGRADATION

The *waste form degradation model* evaluates the interrelationship among the in-package water chemistry, the degradation of the waste form (including cladding), and the mobilization of radionuclides (DIRS 153246-CRWMS M&O 2000, pp. 3-92 to 3-129 and DIRS 155950-BSC 2001, Sections 9.3.1-9.3.2, 10.3.1, and 10.3.4). The model consists of components that:

- Define the radioisotope inventories for representative commercial spent nuclear fuel and codisposal waste packages (this is the inventory abstraction discussed in more detail in Section I.3.1)
- Evaluate in-package water chemistry—in-package chemistry component abstraction (using chemistry lookup tables developed from detailed process model studies and calculations involving other model parameters)
- Evaluate the matrix degradation rates for commercial spent nuclear fuel, DOE-owned spent nuclear fuel, and high-level radioactive waste forms—waste form matrix degradation component abstractions (a temperature- and pH-dependent rate equation with several parameters, such as rate constants and activation energies, represented by statistical distributions)
- Evaluate the rate of Zircaloy cladding degradation (in the case of commercial spent nuclear fuel)—cladding degradation component abstraction with the following components:
  - Initial failure of Zircaloy cladding represented by a triangular distribution (low, mode, and high fraction of rods failed)
  - Creep failure of Zircaloy cladding represented by a series of triangular distributions, with a low value, mode value and high value, for fraction of rods perforated; each distribution for a specific peak waste package temperature range
  - Localized corrosion of Zircaloy cladding represented as a function of the water flux into the waste package, or a small, constant rate if there is no seepage
  - Assumption of total perforation of all stainless-steel cladding at time zero
  - Seismically induced cladding failure as all cladding would fail when a discrete event frequency of 0.0000011 per year occurred

- A cumulative distribution of cladding unzipping rate coefficients; the coefficients are multiplied by the fuel matrix dissolution rate to obtain unzipping velocity

- Effective exposure area of matrix (for radionuclide distribution) as a function of cladding perforation and unzipping

- Evaluate the radionuclide concentrations for aqueous phases—dissolved radionuclide concentration component abstraction (distributions of solubilities as a function of pH and temperature in the waste package; solubilities are also checked for possible limitations due to waste form degradation rate or package inventory)

- Evaluate diffusion of radionuclides in the waste package (DIRS 155950-BSC 2001, Section 10.3.1)

- Evaluate sorption of radionuclides in the waste package (DIRS 155950-BSC 2001, Section 10.3.4)

- Evaluate the waste form colloidal phases—colloidal radionuclide concentration component abstraction (reversible and irreversible colloid models)

I.2.6 ENGINEERED BARRIER TRANSPORT

The waste form would be the source of all radionuclides considered for the engineered barrier system. Radionuclides could be transported downward through the invert and into the unsaturated zone. Transport could occur by diffusion or by advection, depending on the route of the transport. The *engineered barrier system transport abstraction* (DIRS 153246-CRWMS M&O 2000, pp. 3-130 to 3-143) conservatively assumes that diffusion could occur once stress corrosion cracks form, regardless of whether conditions were appropriate for a continuous liquid pathway to exist. Colloid-facilitated transport of radionuclides was included as a transport mechanism. Radionuclides would be transported from the waste package either as dissolved species or bound in, or attached to, colloids.

The abstraction simulates the following transport modes:

- Waste package to invert path
  - Diffusion through stress corrosion cracks
  - Diffusion and advection through patches failed by bulk corrosion

- Invert to unsaturated zone path - Diffusion, sorption and advection through the invert (DIRS 155950-BSC 2001, Section 10.3.3 and 10.3.4)

Diffusion is represented by a diffusion transport equation with an empirical effective diffusivity that is a function of liquid saturation, porosity, and temperature. Sorption on corrosion products is characterized by a linear isotherm (K_D). Advective transport is represented by a liquid transport equation with the velocity determined by the engineered barrier system flow abstraction discussed above.

I.2.7 UNSATURATED ZONE TRANSPORT

Unsaturated zone transport refers to the movement of radionuclides from the engineered barrier system of the proposed repository, through the unsaturated zone, and to the water table. The unsaturated zone would be the first natural barrier to radionuclides that escaped from the potential repository. The unsaturated zone would act as a barrier by delaying radionuclide movement. If the delay was long enough for significant decay of a specific radionuclide, the unsaturated zone could have a significant effect on the ultimate dose from releases of that radionuclide to the environment. The *unsaturated zone transport model* (DIRS 153246-CRWMS M&O 2000, pp. 3-144 to 3-156, and DIRS 155950-BSC 2001, Section 11.3) is used to describe how radionuclides move through the unsaturated zone. The unsaturated zone model considers transport through welded tuff and nonwelded tuff and flow through both the fractures and the rock matrix. In addition, the model accounts for the existence of zeolitic alterations in some regions. These zeolitic tuffs are characterized with low permeability and enhanced radionuclide sorption.

The unsaturated zone water flow would provide the background on which the unsaturated zone transport took place. The model uses the flow fields developed using the unsaturated zone flow model, as described in Section I.2.2. Radionuclides can migrate in groundwater as dissolved molecular species or by being associated with colloids. Five basic processes affect the movement of dissolved or colloidal radionuclides:

- Advection (movement of dissolved and colloidal material with the bulk flow of water) including drift shadow effects on the seepage below the repository (DIRS 155950-BSC 2001, Section 11.3.1)
- Diffusion (movement of dissolved or colloidal material because of random motion at the molecular or colloidal particle scale)
- Sorption (a combination of chemical interactions between solid and liquid phases that reversibly partition radionuclides between the phases)
- Hydrodynamic dispersion (spreading of radionuclides perpendicular to and along the path of flow as they transport caused by localized variations in the flow field and by diffusion)
- Radioactive decay

Sorption is potentially important because it slows, or retards, the transport of radionuclides. Diffusion of radionuclides out of fractures into matrix pores is also a potential retardation mechanism because matrix transport is generally slower than fracture transport. However, sorption and matrix diffusion have less effect on colloids, so radionuclides bound to colloids can be more mobile than radionuclides dissolved in water. Radioactive decay could be important both from quantity reduction of certain radionuclides and the behavior of decay products that can have different transport properties than the decayed radionuclide.

The unsaturated zone transport model was implemented in the TSPA model as an embedded computer code that simulates the three-dimensional transport using a residence-time, transfer-function, particle-tracking technique. The key parameters such as sorption coefficients, diffusion coefficients, dispersivity, fracture spacing, and colloid parameters (partitioning, retardation, colloid size, fraction of colloids exchanging between matrix units) are all input as uncertainty distributions. The results are expressed as breakthrough curves (normalized fraction of total amount of radionuclide arriving at the saturated zone as a function of time) for each radionuclide. These are the inputs for saturated zone transport modeling.

I.2.8 SATURATED ZONE FLOW AND TRANSPORT

The saturated zone at Yucca Mountain is the region beneath the ground surface where rock pores and fractures are fully saturated with groundwater. The upper boundary of the saturated zone is called the water table. The proposed repository would be approximately 300 meters (1,000 feet) above the water table in the unsaturated zone.

As on the surface, underground water flows down the hydraulic gradient. Based on water-level observations in area wells, groundwater near Yucca Mountain flows generally in a north-to-south direction. The major purpose of the *saturated zone flow and transport model* (DIRS 153246-CRWMS M&O 2000, pp. 3-156 to 3-174, and DIRS 155950-BSC 2001, Sections 12.3.1 and 12.3.2) is to evaluate the migration of radionuclides from their introduction at the water table below the potential repository to the point of release to the biosphere (for example, a water supply well). Radionuclides can move through the saturated zone either as a dissolved solute or associated with colloids. The input to the saturated zone is the spatial and temporal distribution of mass flux of radionuclides from the unsaturated zone. The output of the saturated zone flow and transport model is a mass flux of radionuclides in the water used by a hypothetical farming community.

I.2.8.1 Saturated Zone Flow

The *saturated zone flow submodel* (DIRS 153246-CRWMS M&O 2000, pp. 3-157 to 3-164 and DIRS 155950-BSC 2001, Section 12.3.1) takes inputs from the unsaturated zone flow submodel and produces outputs, in the form of flow fields, for the saturated zone transport submodel. The saturated zone flow submodel incorporates a significant amount of geologic and hydrologic data taken from drill holes near Yucca Mountain. The saturated groundwater flow in the vicinity of Yucca Mountain can be estimated by knowing the porosity of the flow media, the hydraulic conductivity, and the recharge of water into the flow media. The primary tool used to describe saturated zone flow is a numerical model formulated in three dimensions. The three-dimensional saturated zone flow model has been developed specifically to determine the groundwater flow field at Yucca Mountain. The model was used to produce a library of flow fields (maps of groundwater fluxes). In addition, a GoldSim-based one-dimensional version of the model was used to provide flow information for a one-dimensional model of transport of radionuclide decay products.

I.2.8.2 Saturated Zone Transport

The *saturated zone transport submodel* (DIRS 153246-CRWMS M&O 2000, pp. 3-157 to 3-164, and DIRS 155950-BSC 2001, Section 12.3.2) takes inputs in the form of radionuclide mass fluxes from the unsaturated zone transport submodel and produces outputs in the form of radionuclide mass fluxes to the biosphere model. The saturated zone transport model incorporates a substantial amount of laboratory and field data taken from a variety of sources.

Radionuclides released from a repository at Yucca Mountain to the groundwater would enter the saturated zone beneath the repository and would be transported first southeast, then south, toward the Amargosa Desert. The radionuclides could be transported by the groundwater in two forms: as dissolved species or associated with colloids. Dissolved species typically consist of radionuclide ions complexed with various groundwater species, but still at molecular size. Colloids are particles of solids, typically clays, silica fragments, or organics, such as humic acids or bacteria, that are larger than molecular size, but small enough to remain suspended in groundwater for indefinite periods. Colloids are usually considered to have a size range of between a nanometer and a micrometer. A radionuclide associated with a colloid can transport either attached to the surface or bound within the structure of the colloid.

Transport through the saturated zone was primarily modeled using a three-dimensional particle-tracking method (DIRS 153246-CRWMS M&O 2000, pp. 3-168 to 3-169). The three-dimensional transport model was not used directly by the TSPA model. It was used to generate a library of breakthrough curves—distributions of transport times that are used, along with a time-varying source term from the unsaturated zone, to calculate the releases at the geosphere/biosphere boundary. The model accounts for the flow of groundwater and its interaction with varying media along the flow path. In the volcanic rocks that comprise the saturated media in the immediate vicinity of Yucca Mountain, groundwater flows primarily through fractures, while a large volume of water is held relatively immobile in the surrounding rock matrix. Radionuclides would travel with the moving fracture water but, if dissolved, could diffuse between the matrix water and fracture water. This transfer between fracture and matrix water is characteristic of a dual-porosity system. The saturated zone transport model is a dual-porosity model.

The media at greater distances from Yucca Mountain are alluvial gravels, sands and silts. The model simulates these areas as a more uniform porous material. While there is a possibility for channelized flow in the alluvium, current data indicate little evidence of dual-porosity behavior that would indicate this (DIRS 155950-BSC 2001, p. 12-23).

A one-dimensional saturated zone transport model was used to account for decay and ingrowth during transport. This model was incorporated directly in the GoldSim model as a series of pipes. The advantage of using the one-dimensional model is that the radionuclide masses can be accounted for directly. The disadvantage is that the flow and transport geometry is necessarily simplified.

I.2.9 BIOSPHERE

If the radionuclides were removed from the saturated zone in water pumped from wells, the radioactive material could result in dose to humans in several ways. For example, the well water could be used to irrigate crops that would be consumed by humans or livestock, to water stock animals that would be consumed by humans as dairy or meat products, or to provide drinking water for humans. In addition, if the water pumped from irrigation wells evaporated on the ground surface, the radionuclides could be left as fine particulate matter that could be picked up by the wind and inhaled by humans. The *biosphere pathway model* (DIRS 153246-CRWMS M&O 2000, pp. 3-175 to 3-187) was used to predict radiation exposure to a person living in the general vicinity of the repository if there was a release of radioactive material to the biosphere after closure of the proposed repository. The model uses a biosphere dose conversion factor that converts saturated zone radionuclide concentrations to annual individual radiation dose. The biosphere dose conversion factor was developed by analyzing the multiple pathways through the biosphere by which radionuclides can affect a person. The biosphere scenario assumed a *reference person* living in the Amargosa Valley region at various distances from the repository. People living in the Town of Amargosa Valley would be the group most likely to be affected by radioactive releases. An adult who lives year-round at this location, uses a well as the primary water source, and otherwise has habits (such as the consumption of local foods) similar to those of the inhabitants of the region. Because changes in human activities over millennia are unpredictable, the analysis assumed that the present-day reference person described future inhabitants. Strict definitions for the reference person (the Reasonably Maximally Exposed Individual, or RMEI) have been prescribed in 40 CFR Part 197. The chemically toxic materials were not evaluated in the biosphere model because there are no usable comparison values for radiologic and nonradiologic dose. Rather, a separate analysis of concentrations of these materials was made. The concentrations were then compared to available regulatory standards, such as the Maximum Contaminant Level Goal if available, or to the appropriate Oral Reference Dose.

The biosphere is the last component in the chain of TSPA model subsystem components. There are two connections between the biosphere submodel and other TSPA model submodels. One is for the groundwater irrigation scenario (nominal scenario), where the biosphere is coupled to the saturated zone flow and transport model; and the other is for the disruptive scenario, where the biosphere is coupled to the volcanic dispersal model. For the human intrusion scenario, the biosphere model is coupled with the saturated zone flow and transport model, and the event is treated as a perturbation to the nominal scenario. The groundwater path doses are based on specific paths of groundwater flow derived from regional data.

The primary result of the biosphere modeling is the construction of biosphere dose conversion factor distributions for the groundwater-release scenarios and the volcanic-ash-release scenario (DIRS 157307-BSC 2001, all). For the nominal scenario, well withdrawal of groundwater is the source of water for drinking, irrigation, and other uses. A farming community at the point of withdrawal would use the water at a rate based on surveys of current usage. The hypothetical farming community consists of between 15 and 25 farms supporting about 100 people. All radionuclides reaching this community in groundwater were assumed to be mixed in the volume of water that the community would use (this is the concept of full "capture" of the total plume of contamination). The water usage was input as a distribution of values based on current water usage data. The exposure pathways routes taken by radionuclides through the biosphere from the source to an individual are typical for a farming community in this environment. Farming activities usually involve more exposure pathways than other human activities in the Yucca Mountain region, including ingestion of contaminated water and locally produced food as well as inhalation and direct exposure from soil contamination intensified by the significant outdoor activity inherent in a farming lifestyle.

During periods of very wet climate, the Amargosa Desert is actually a lake and the irrigated farm scenario on which the biosphere model is based is not applicable. This is consistent with regulatory guidance that indicates no attempt should be made to project future human behavior and lifestyles (even if driven by climate change). The approach used is conservative because the use of groundwater for irrigation and domestic purposes has the effect of bringing up relatively concentrated solutions of contaminants. In a scenario where the Amargosa Desert is a lake (as it was 20,000 years ago), this large quantity of water would dilute the radionuclides to very low concentrations. Furthermore, the use of water would follow a greatly altered pattern. Consideration of all this leads to the conclusion that peak doses would be much lower than those projected in the current analysis.

I.2.10 VOLCANISM

Igneous activity (flow of volcanic material as in a volcanic eruption) has been identified as a disruptive event that has a potential to affect repository long-term performance. Yucca Mountain is in a region that has had repeated volcanic activity in the geologic past. Although the probability of recurrence at Yucca Mountain during the next 10,000 years is small, it is greater than 1 chance in 10,000 and is, therefore, retained as a scenario.

If igneous activity occurred at Yucca Mountain, possible effects on the repository could be grouped into three areas:

- Igneous activity that would not directly intersect the repository (can be shown to have no effect on dose from the repository)
- Volcanic eruptions in the repository that would result in waste material being entrained in the volcanic magma or pyroclastic material, bringing waste to the surface (resulting in atmospheric transport of volcanic ash contaminated with radionuclides and subsequent human exposure downwind)
- An igneous intrusion intersecting the repository (no eruption but damage to waste packages from exposure to the igneous material that would enhance release to the groundwater and, thus, enhance transport to the biosphere)

Based on studies of past activity in the region, probabilities for different types of igneous activity were estimated. Each type of event was described in detail based on observation of effects of past activities. These descriptions include geometry of intrusions, geometry of eruptions, physical and chemical properties of volcanic materials, eruption properties (velocity, power, duration, volume, and particle characteristics). Most of the parameters describing the igneous activity were entered in the modeling as probability distributions.

A collection of different modeling approaches was used to develop responses to the different types of activity described above (DIRS 153246-CRWMS M&O 2000, pp. 3-187 to 3-216 and DIRS 157307-BSC 2001, Enclosure 1).

I.2.11 HUMAN INTRUSION

Human intrusion was modeled based on a stylized scenario that is a conceptualization of the assumptions outlined in the Environmental Protection Agency standard (DIRS 157307-BSC 2001, Enclosure 1). The assumptions are based on recommendations of the National Research Council of the National Academy of Sciences. The Council observed that it is not possible to predict human behavior over the extremely long periods of concern and prescribed the scenario as a reasonable representation of typical inadvertent intrusion.

The models used were the same as those for the nominal scenario, except a source term was introduced for the time of the intrusion. This source term is characteristic of direct penetration of a waste package with a drill bit (DIRS 157307-BSC 2001, Enclosure 1).

I.2.12 NUCLEAR CRITICALITY

A nuclear criticality occurs when sufficient quantities of fissionable materials come together in a precise manner and the required conditions exist to start and sustain a nuclear chain reaction. One of the required conditions is the presence of a moderator, such as water, in the waste package. The waste packages would be designed to make the probability of a criticality occurring inside the waste package extremely small. In addition, based on an analysis of anticipated repository conditions, it is very unlikely that a sufficient quantity of fissionable materials could accumulate outside the waste packages in the precise configuration and with the required conditions to create a criticality. If, somehow, an external criticality was to occur, analyses indicate that it would have only minor effects on repository performance. In the unlikely event that a criticality occurred, there would be a short-duration localized rise in temperature and pressure, as well as an insignificant increase in the repository radionuclide inventory. No measurable effect on repository performance would result from this event (DIRS 153849-DOE 2001, p. 4-416).

I.2.13 ATMOSPHERIC RADIOLOGICAL CONSEQUENCES

In addition to the groundwater pathway, the analysis of long-term performance evaluated potential consequences of the release of radioactive gases into the environment. An analysis separate from the groundwater modeling described in the previous sections was used to forecast such consequences. The model used results from the waste package degradation models to evaluate when waste packages and fuel cladding would fail and, therefore, release contained radioactive gases. This model provided input to release and transport estimates for the atmospheric pathway. Section I.7 contains details of this analysis.

I.3 Inventory

This section discusses the inventories of waterborne radioactive materials used to model radiological impacts and of some nonradioactive, chemically toxic waterborne materials used in the repository environment that could present health hazards. This section also discusses the inventory of atmospheric radioactive materials.

I.3.1 INVENTORY FOR WATERBORNE RADIOACTIVE MATERIALS

There would be more than 200 radionuclides in the materials placed in the repository (see Appendix A of this EIS). In the Proposed Action, these radionuclides would be present in five basic waste forms: commercial spent nuclear fuel, mixed-oxide fuel and plutonium ceramic (called here *plutonium disposition waste*), borosilicate glass formed from liquid wastes on various DOE sites known as high-level radioactive waste, DOE-owned spent nuclear fuel, and naval spent nuclear fuel (DIRS 153246-CRWMS M&O 2000, Figure 3.5-4). In the repository, these wastes would be placed in several different types of waste packages of essentially the same construction but of varying sizes and with varying types of internal details. (DIRS 150558-CRWMS M&O 2000, Section 4.3). It is neither necessary nor practical to model the exact configuration of waste packages. The individual details of each package design are not significant parameters in modeling the processes involved in waste package degradation, waste form degradation, and radionuclide transport from the engineered barrier system. Constructing a TSPA model with each individual package and its unique design would result in a computer model too large to run on any available computer in a practical time. Therefore two representative types of waste packages were modeled in representative zones of the repository. The development of the two representative types of waste packages and their radionuclide inventories is the process of abstraction.

An abstracted inventory was used in the analysis of long-term groundwater impacts in much the same way as many other Features, Processes and Events were abstracted. The TSPA model is a high-level system model that performs hundreds of trials in a Monte Carlo framework. To make such a calculation tractable, it was necessary to reduce highly complex descriptions or behaviors to simplified concepts that capture the essential characteristics. In the case of inventory, the highly complex array of waste streams for the five fundamental waste categories (commercial spent nuclear fuel, plutonium-disposition waste, high-level radioactive waste, DOE-owned spent nuclear fuel, and naval spent nuclear fuel) were considered in developing the abstraction to representative waste packages that capture the essential features of the total inventory of radionuclide materials. The waste packages in the repository can be represented in two package types: a commercial spent nuclear fuel waste package and a codisposal waste package containing DOE spent nuclear fuel and high-level radioactive waste glass. The naval spent nuclear fuel was modeled as part of the commercial spent nuclear fuel. The plutonium disposition waste was split into the commercial spent nuclear fuel packages (mixed-oxide fuel) and codisposal package (immobilized plutonium within a high-level radioactive waste container) (DIRS 154841-BSC 2001, all).

The abstracted inventory has been carefully developed to maintain essential characteristics of the waste forms for the purpose of input to the TSPA model. As such, the TSPA abstracted inventory cannot be used for any other purpose, because it is not reality but rather a representation of reality that works only for the purpose intended. The averaging, blending, and screening of radionuclides to reduce the total number, while retaining essential physical characteristics of the waste, were all tailored to the TSPA model. Therefore, any attempt to compare this abstracted inventory with other abstractions used for other analyses in the repository will not be valid. The only essential comparison that can be made is that of the fundamental inputs to the abstraction process to fundamental inputs used in other analyses.

The abstraction of the inventory is shown in Figure I-2. In the figure, items in boxes are references to documents that either describe an analysis or are a data transmittal. The items not in boxes (next to the arrows) are the data produced from a documented analysis and used in another documented analysis.

Figure I-2 identifies four fundamental inputs:

- Input from DOE Environmental Management's National Spent Nuclear Fuel Program that identifies the characteristics of all DOE-owned spent nuclear fuel that would be sent to the repository (DIRS 110431-INEEL 1999, all)

- A body of high-level radioactive waste data collected from the EIS Data Call of 1997 (DIRS 104418-Rowland 1997); this includes information concerning high-level radioactive waste and plutonium-disposition waste

- A body of data that forms the database for commercial spent nuclear fuel; this is a collection of documents including key documents such as DOE/RW-0184 (DIRS 102588-DOE 1992, all) in its various revisions

- The *Monitored Geologic Repository Project Description Document* (DIRS 151853-CRWMS M&O 2000, all).

These four inputs were manipulated in various analyses that were brought together in the inventory abstraction (DIRS 157307-BSC, 2001, all) and are shown as the box at the bottom center of the figure. The fundamental data on commercial spent nuclear fuel was first processed in three analyses: simulation of a delivery schedule to the repository (DIRS 119348-CRWMS M&O 1999, all) (this was done using a standard computer code called CALVIN and source term studies for boiling-water reactor and pressurized-water reactor fuel that describe the typical radionuclide inventories for these spent fuels (DIRS 136428-CRWMS M&O 1999, all) (DIRS 136429-CRWMS M&O 1999, all). The CALVIN results are part of the input to the source term studies. All of the commercial spent nuclear fuel studies were then combined in a packaging study that describes the resulting spent nuclear fuel packages in the detailed design of the repository (DIRS 138239-CRWMS M&O 2000, all). The fundamental information on high-level radioactive waste was analyzed to determine decay and ingrowth of radionuclides in the waste and obtain inventory as a function of time (DIRS 147072-CRWMS M&O 1999, all). This study used the ORIGEN-S computer code, a standard code for determining inventories as a function of time. Fundamental data on DOE-owned spent nuclear fuel was analyzed to determine a packaging strategy (DIRS 149005-CRWMS M&O 2000, all). The results of this study identified three canister types and their inventories. At this point the results of commercial spent nuclear fuel, high-level radioactive waste, and DOE-owned spent nuclear fuel analyses were brought together in another analysis to develop a set of 13 standard package configurations (DIRS 153909-BSC 2001, all). This result was the basic set of detailed package configurations for the repository.

Another important analysis is the screening analysis. In this analysis, the contribution of specific radionuclides to inhalation and ingestion dose was determined and the radionuclides were ranked according to their contribution to total dose of all radionuclides (DIRS 153597-CRWMS M&O 2000, all). The metric for screening radionuclides is the radiation dose that a radionuclide could impose on a human living in the vicinity of Yucca Mountain. Identification of the important dose contributors is based on an estimate of the amount of radionuclides that could reach a human (DIRS 136383-CRWMS M&O 2000, all). Identification of the important dose contributors involves three steps:

1. For the waste form under consideration, the relative dose contribution from an individual radionuclide is calculated by multiplying its inventory abundance (in terms of its radioactivity) by its dose conversion factor (a number that converts an amount of a radionuclide into the dose that a human would incur if the radionuclide was ingested, inhaled, or came in close proximity). This multiplication gives a result that can be compared to values derived in the same manner for other radionuclides to determine the more important contributors to the dose.

2. The individual radionuclides are ranked, with the highest contributor to the dose given the highest ranking, and the percent contribution of each radionuclide in the list to the total dose (the sum of the doses from the radionuclides in the list) is calculated.

3. Radionuclides that are included in the analysis are the highest-ranked radionuclides that, when their dose contributions are combined, produce 95 percent of the dose.

These steps identify which radionuclides would be included in the dose estimate, if all the radionuclides in a waste form were released to the environment in proportion to their inventory abundance. However, radionuclides are not always released in proportion to their inventory abundance. Factors that can affect releases of radionuclides, depending on the scenario being considered, include radionuclide longevity, solubility, and transport affinity.

Radionuclide longevity is the lifetime of a radionuclide before it decays. Solubility is the amount of a radionuclide that will dissolve in a given amount of water. Transport affinity is a radionuclide's potential for movement through the environment. This movement can involve a number of mechanisms, for example: fracture flow (the movement of radionuclides with water flowing in fractures), matrix diffusion (the diffusion of radionuclides from water in the fractures into water in the matrix), or colloidal-facilitated transport (the movement of radionuclides associated with small particles of rock or waste form degradation products). Transport affinity is not a measurable property, but a qualitative description of the likelihood of transport. If a group of radionuclides is transported via a particular mechanism, and that mechanism dominates release, the group of radionuclides will be preferentially released (relative to radionuclides not in the group) to the environment. If a radionuclide has a short half-life, it will have a higher activity in the waste form at early times (close to repository closure); however, at later times, the radionuclide will have all but disappeared from the waste form. If a radionuclide is not soluble in the near-field environment around the waste package, it may not be released to the environment through groundwater transport, even if it is abundant and available.

Because radionuclide longevity, solubility, and transport affinity can affect releases of radionuclides, the identification of important dose contributors includes examination of possible "what-if" scenarios that could result in releases of radionuclides to the environment. For example, "What if radionuclide releases are the result of a colloidal transport mechanism? If the steps described above are applied to the subset of radionuclides that could be released through a colloidal-transport mechanism (radionuclides that readily bind to rock and colloidal particles), which of those radionuclides would be identified as the important contributors to dose?" Or, "What if a volcanic direct release to the environment occurs? If the steps described above are applied to the radionuclides present in the waste form in a direct release, which of those radionuclides would be identified as the important contributors to dose?" The radionuclide screening examined over 1,200 potential what-if scenarios and identified the important dose contributors for each one. The cases examined consider times from 100 to 1 million years after repository closure (100, 200, 300, 400, 500, 1,000, 2,000, 5,000, 10,000, 100,000, 300,000, and 1,000,000 years); eight waste forms (average and bounding pressurized-water reactor fuel, average and bounding boiling-water reactor fuel, average and bounding DOE spent nuclear fuel, and average and bounding DOE high-level radioactive waste); three transport affinity groups (highly sorbing, moderately sorbing, and slightly to nonsorbing); and two exposure pathways (inhalation and ingestion).

In addition to the radionuclides selected based on contribution to dose, other radionuclides (in particular radium-226 and radium-228) must be considered because of the groundwater protection requirements in 40 CFR Part 197. Other radionuclides must also be considered in the analysis because they belong to decay chains; they must be included to accurately track other members of the decay chains. (A decay chain is a sequence of radionuclides that, because of radioactive decay, change from one to the other; thus, the amount of one is dependent on the amounts of the others.)

The complete list of radionuclides produced by the screening merges all the lists of radionuclides developed from the various scenarios. For example, if a radionuclide is important for estimating the dose from DOE spent nuclear fuel, it is included in the analysis even though these waste forms would occupy a small fraction of the repository. Similarly, if a radionuclide is important for estimating the dose from the highly sorbing transport group, it is included in the analysis, even if analyses show that colloid transport is a minimal contributor to release.

The inventory abstraction then took as input the 13 configurations, the design of the repository, the screening analysis, and a special americium-241 ingrowth analysis (DIRS 153596-CRWMS M&O 2001, all). The abstraction provided two fundamental results:

- The total initial inventory for the TSPA model for the Proposed Action represented as the quantity of radionuclides in two representative waste package types. The total number of radionuclides represented has been reduced by a screening process with two criteria: elimination of all radionuclides with a half-life less than 20 years and inclusion of all radionuclides that contribute at least 95 percent of the total radiological dose.

- A recommended list of radionuclides to track for each of three scenarios: nominal scenario, disruptive events (volcanism) scenario, and human intrusion scenario. Not all radionuclides in the master list are necessarily included in a particular scenario. This is because some radionuclides are not important in some scenarios.

Additional analyses for this EIS included consideration of two other inventories that are not part of the Proposed Action. These analyses supported the analysis of cumulative impacts from possible future actions. The first of these is the addition of more commercial spent nuclear fuel. The combined inventory of the Proposed Action and this additional commercial spent nuclear fuel is referred to as Inventory Module 1. In addition, a category for Greater-Than-Class-C plus Special-Performance-Assessment-Required materials (Inventory Module 2 only) could be added in the future. The waste packages in this calculation include the commercial spent nuclear fuel packages and DOE spent nuclear fuel and high-level radioactive waste codisposal packages described in DIRS 150558-CRWMS M&O (2000, all). This EIS assumes that the Inventory Module 2 Greater-Than-Class-C and Special-Performance-Assessment-Required waste would be packaged in codisposal waste packages (DIRS 155393-CRWMS M&O 2000, Attachment II). The numbers of idealized waste packages used in the calculations are listed in Table I-4.

Table I-4. Modeled number of idealized waste packages by category type for the abstracted inventories of the Proposed Action, Inventory Module 1, and Inventory Module 2.

Waste category	Proposed Action	Inventory Module 1	Inventory Module 2
Commercial spent nuclear fuel[a]	7,860	11,754	0[b]
DOE spent nuclear fuel/high-level radioactive waste codisposal	3,910	4,877	0[b]
Greater-Than-Class-C	0	0	201
Special-Performance-Assessment-Required	0	0	400
Total	***11,770***	***16,631***	***601***[b]

a. 300 U.S. Navy spent nuclear fuel waste packages are modeled as commercial spent nuclear fuel waste packages.
b. Inventory Module 2 would include all packages in Inventory Module 1 plus the numbers shown for Greater-Than-Class-C and Special-Performance-Assessment Required waste packages; however, for modeling purposes only the *incremental increase* in the number of waste packages was modeled and the result added to the result for Inventory Module 1 impacts to estimate Inventory Module 2 impacts.

The physical properties of the various waste forms to be placed in the proposed Yucca Mountain repository are described in detail in DIRS 151109-CRWMS M&O (2000, all).

I.3.1.1 Radionuclide Inventory Used in the Model of Long-Term Performance for Proposed Action

The tabulated per-waste-package inventory used in the Proposed Action calculations is listed in Table I-5.

I.3.1.2 Radionuclide Inventory Used in the Model of Long-Term Performance for Inventory Module 1

The abstracted per-waste-package radionuclide inventory used for the Proposed Action also applies to additional waste packages for the expansion of the repository to include all potential commercial and DOE waste under Inventory Module 1. In other words, the number of packages is increased for Inventory Module 1 compared to the Proposed Action, but the content of each individual idealized waste package remains the same.

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Table I-5. Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package for commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste for Proposed Action, Inventory Module 1, and Inventory Module 2.[a,b]

Radionuclide	Commercial spent nuclear fuel waste packages	Codisposal waste packages	
		DOE spent nuclear fuel	High-level radioactive waste
Actinium-227	0.00000309	0.000113	0.000467
Americium-241	10,900	117	65.7
Americium-243	1,290	1.49	0.399
Carbon-14	1.37	0.0496	0.00643
Cesium-137	5,340	112	451
Iodine-129	1,800	25.1	48
Neptunium-237	4,740	47.9	72.3
Proactinium-231	0.00987	0.325	0.796
Lead-210	0	0.000000014	0.000000114
Plutonium-238	1,510	6.33	93.3
Plutonium-239	43,800	2,300	3,890
Plutonium-240	20,900	489	381
Plutonium-242	5,410	11.1	7.77
Radium-226	0	0.00000187	0.0000167
Radium-228	0	0.00000698	0.00000319
Strontium-90	2,240	55.4	288
Technetium-99	7,680	115	729
Thorium-229	0	0.0266	0.00408
Thorium-230	0.184	0.0106	0.00782
Thorium-232	0	14,900	7,310
Uranium-232	0.0101	0.147	0.000823
Uranium-233	0.07	214	11.1
Uranium-234	1,830	57.2	47.2
Uranium-235	62,800	8,310	1,700
Uranium-236	39,200	853	39.8
Uranium-238	7,920,000	509,000	261,000

a. Source: DIRS 154841-BSC (2001, Table 36, p. 38).
b. The idealized waste packages in the simulation (model) are based on the inventory abstraction. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the potential repository would be different. The numbers of idealized waste packages modeled for various inventory abstractions are listed in Table I-4.

I.3.1.3 Radionuclide Inventory Used in the Model of Long-Term Performance for Inventory Module 2

Wastes with concentrations above Class-C limits (shown in 10 CFR 61.55, Tables 1 and 2) for long and short half-life radionuclides, respectively, are called Greater-Than-Class-C low-level waste. These wastes generally are not suitable for near-surface disposal. The Greater-Than-Class-C waste inventory is discussed in detail in Appendix A, Section A.2.5, of this EIS.

DOE Special-Performance-Assessment-Required low-level radioactive waste could include production reactor operating wastes, production and research reactor decommissioning wastes, non-fuel-bearing components of naval reactors, sealed radioisotope sources that exceed Class-C limits for waste classification, DOE isotope production related wastes, and research reactor fuel assembly hardware. The Special-Performance-Assessment-Required waste inventory is discussed in detail in Appendix A.

The final disposition method for Greater-Than-Class-C and Special-Performance-Assessment-Required low-level radioactive waste is not known. If these wastes were to be placed in a repository, they would be placed in canisters before shipment. This appendix assumes the use of a canister similar to the naval dual-purpose canister described in Section A.2.2.5.6 of Appendix A of this EIS.

IDEALIZED WASTE PACKAGES

The number of waste packages used in the performance assessment simulations do not exactly match the number of waste packages projected for the Proposed Action.

The TSPA model uses two types of *idealized waste packages* (commercial spent nuclear fuel package and co-disposal package), representing the averaged inventory of all the actual waste packages used for a particular waste category.

While the number of idealized waste packages varies from the number of actual waste packages, the total radionuclide inventory represented by all of the idealized waste packages collectively is representative of the total inventory, for the radionuclides analyzed, given in Appendix A of this EIS for the purposes of analysis of long-term performance. The abstracted inventory is designed to be representative for purposes of analysis of long-term performance and cannot necessarily be used for any other analysis, nor can it be directly compared to any other abstracted inventory used for other analyses in this EIS.

Table I-6 lists existing and projected volumes through 2055 for the three Greater-Than-Class-C waste sources. DOE conservatively assumes 2055 because that year would include all Greater-Than-Class-C low-level waste resulting from the decontamination and decommissioning of commercial nuclear reactors. The projected volumes conservatively reflect the highest potential volume and activity expected based on inventories, surveys, and industry production rates.

The data concerning the volumes and projections of Greater-Than-Class-C low-level waste are from Appendix A-1 of the *Greater-Than-Class-C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics* (DIRS 101798-DOE 1994, all). That appendix provides detailed radioactivity reports for such waste currently stored at nuclear utilities.

The only difference between Inventory Modules 1 and 2 is the addition of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes under Inventory Module 2. This represents an incremental increase in the total inventory for Inventory Module 2 over Inventory Module 1, with no difference in the temperature operating mode or the areal extent of the repository disposal area. Because of this, calculations for analysis of long-term performance for Inventory Module 2 were performed considering only Greater-Than-Class-C and Special-Performance-Assessment-Required waste inventories, and the results treated as an incremental increase to the impacts predicted for analysis of long-term performance of Inventory Module 1.

Table I-6. Greater-Than-Class-C low-level waste volumes (cubic meters)[a] by source.[b]

Source	1993	2055
Nuclear electric utility	26	1,300
Sealed sources	39	240
Other	74	470
Totals	***139***	***2,010***

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. Source: DIRS 101798-DOE (1994, Tables 6-1 and 6-3).

The radionuclide inventory used for Inventory Module 2 (Greater-Than-Class-C and Special-Performance-Assessment-Required materials) is described and tabulated in Appendix A of this EIS and the abstracted per-package inventory developed from these data is listed on Table I-7. The details of

Table I-7. Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package for Greater-Than-Class-C and Special-Performance-Assessment-Required waste (grams per waste package) under Inventory Module 2.[a,b]

Radionuclide	Greater-Than-Class-C and Special-Performance-Assessment-Required	Radionuclide	Greater-Than-Class-C and Special-Performance-Assessment-Required
Actinium-227	0	Plutonium-242	0.00614
Americium-241	40	Radium-226	0.0504
Americium-243	0.00151	Strontium-90	0.82
Carbon-14	28.9	Technetium-99	568
Cesium-137	771	Thorium-229	0
Iodine-129	0.000705	Thorium-230	0
Neptunium-237	0	Uranium-232	0.00000287
Protactinium-231	0	Uranium-233	0.00419
Lead-210	0	Uranium-234	0
Plutonium-238	1.56	Uranium-235	0
Plutonium-239	2,860	Uranium-236	0
Plutonium-240	0.0123	Uranium-238	563,000
Plutonium-241	0.0207		

a. Source: DIRS 157307-BSC (2001, Enclosure 1).
b. The idealized waste packages in the simulation (model) are based on the inventory abstraction. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the potential repository would be different.

obtaining the per-package inventory for Greater-Than-Class-C and Special-Performance-Assessment-Required materials are described in DIRS 157307-BSC (2001, Attachment III).

I.3.2 INVENTORY FOR WATERBORNE CHEMICALLY TOXIC MATERIALS

Waterborne chemically toxic materials that present a potential human health risk would be present in materials disposed of in the repository. The most abundant of these materials would be nickel, chromium, and molybdenum (which would be used in the waste package) and uranium (in the disposed waste). Uranium is both a chemically toxic and a radiological material. Screening studies were conducted to determine if any of these or other materials would be released in sufficient quantities to have a meaningful impact on groundwater quality.

An inventory of chemical materials to be placed in the repository under the Proposed Action was prepared. The inventories of the chemical components in the repository were combined into four groups:

- Materials not part of engineered barrier system
- Components of the engineered barrier system including:
  - Titanium drip shields
  - Alloy-22 in the outer layer of the waste packages
  - Stainless steel in the inner layer of the waste packages
- Other materials internal to the waste packages
- High-level radioactive waste

These materials were organized into groups with similar release times for use in the screening study. Table I-8 lists the chemical inventories. Plutonium is not listed in Table I-8 because, while it is a heavy metal and therefore could have toxic effects, its radiological toxicity far exceeds its chemical toxicity (DIRS 102205-DOE 1998, Section 2.6.1). In addition, while there are radiological limits set for exposure

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Table I-8. Inventory (kilograms)[a] of chemical materials placed in the Proposed Action repository.

	Inventory				
Element	Not part of engineered barrier system	Engineered barrier system components exposed before waste package failure	Internal to waste package including inner sleeve	High-level radioactive waste[b]	Totals
Aluminum	0	0	2,452,400	0	2,452,400
Barium	0	0	50,000	74,000[c]	124,000
Boron	0	0	197,400	0	197,400
Cadmium	0	0	3,401	43,000	46,400
Carbon	318,738	547	5,000	0	324,285
Chromium	0	23,735,000	26,414,000	0	50,149,000
Cobalt	0	0	27,000	0	27,000
Copper	243,800	0	3,000	0	246,800
Iron	111,916,880	1,190,000	161,695,000	0	274,801,880
Lead	0	0	0	2,000	2,000
Magnesium	0	0	12,000	0	12,000
Manganese	1,189,576	575,880	3,732,100	0	5,497,556
Mercury	0	0	0	200	200
Molybdenum	0	17,307,000	3,839,100	0	21,146,100
Nickel	0	60,797,000	18,659,100	0	79,456,100
Phosphorus	39,842	820	91,200	0	131,862
Selenium	0	0	0	300	300
Silicon	330,122	18,226	1,680,500	0	2,028,848
Sulfur	39,842	547	68,200	0	108,589
Titanium	0	4,148,000	2,000	0	4,150,000
Uranium	0	0	70,000,000	0	70,000,000
Vanadium	0	377,600	0	0	377,600
Zinc	0	0	3,000	0	3,000

a. To convert kilograms to pounds, multiply by 2.2046

b. The high-level radioactive waste form to be placed in the potential repository would not exhibit the Characteristic of Toxicity as measured by the Toxicity Characteristic Leaching Procedure (40 CFR 261.24).

c. Includes barium grown in from decay of all of the cesium.

to plutonium, no chemical toxicity benchmarks have been developed for this element. Therefore, lacking data to analyze chemical toxicity, plutonium was not analyzed for the chemical screening.

I.3.3 INVENTORY FOR ATMOSPHERIC RADIOACTIVE MATERIALS

The only radionuclide that would have a relatively large inventory and a potential for gas transport would be carbon-14. Iodine-129 can exist in a gas phase, but it is highly soluble and therefore likely to dissolve in groundwater rather than migrate as a gas. Radon-222 is a gas, but would decay to a solid isotope before escaping from the repository region (see Section I.7.3). After carbon-14 escaped from the waste package, it could flow through the rock in the form of carbon dioxide. About 2 percent of the carbon-14 in commercial spent nuclear fuel occurs in a gas phase in the space (or *gap*) between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92). The gas-phase inventory consists of 0.122 curie of carbon-14 per commercial spent nuclear fuel waste package. Table I-9 lists the carbon-14 inventory for commercial spent nuclear fuel under the Proposed Action and Inventory Modules 1 and 2.

I.4 Extension of TSPA Methods and Models for EIS Analysis of Long-Term Performance

The TSPA model nominal scenario is equivalent to the Proposed Action inventory for an individual at the RMEI location [approximately 18 kilometers (11 miles) downgradient from the proposed repository]. Details on the adaptations, extensions, and modifications to the software and models used for the TSPA

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Table I-9. Carbon-14 gaseous inventory from commercial spent nuclear fuel (curies).[a]

Modeled inventory	Quantity[b]
Proposed Action	959
Module 1	1,434
Module 2	1,434

a. Impacts of carbon-14 in solid form are addressed as waterborne radioactive material impacts.

b. Based on 0.122 curie of carbon-14 per commercial spent nuclear fuel waste package, based on 2 percent of the carbon-14 in commercial spent nuclear fuel existing as a gas in the gap between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92).

model necessary to analyze impacts under Inventory Modules 1 and 2 and at additional individual locations 30 and 60 kilometers (19 and 37 miles) downgradient from the repository are presented in this section.

I.4.1 METHODOLOGY

The calculations presented in this EIS were performed using the numerical code GoldSim, Version 7.17.200 (DIRS 155182-BSC 2001, all). The GoldSim calculations were performed for the conceptual/process modeling of the proposed Yucca Mountain Repository described in the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, all) and expanded upon in the *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, all; DIRS 154659-BSC 2001, all).

The performance assessment calculations for both the TSPA–Site Recommendation, the Supplemental Science and Performance Analyses, and the analysis of long-term performance calculations described in this EIS were performed within a probabilistic framework combining the most likely ranges of behavior for the various component models, processes, and corresponding parameters included in the overall conceptual/process model describing the performance of the repository.

The GoldSim software integrated the submodels using a Monte-Carlo simulation-based methodology to create multiple random combinations of the uncertain variables, and computed the probabilistic performance of the entire waste-disposal system in terms of annual individual dose. The GoldSim software calculated radionuclide release and radiological dose (the annual committed effective dose equivalent as defined in 40 CFR 197.2 from individual radionuclides and the total annual dose due to all radionuclides released from the repository from failed waste packages). In this EIS, the annual committed effective dose equivalent is referred to as the annual individual dose. GoldSim calculated the total annual dose for 300 realizations of the model configuration for the nominal scenario, and 5,000 realizations for the igneous activity scenario, using randomly selected values of distributed parameters for each realization. The calculation results are available in two main forms: (1) probability distributions for peak dose to an individual, and (2) time histories of annual dose to an individual.

The recently promulgated Environmental Protection Agency Final Rule 40 CFR Part 197 stipulates that the performance assessment of the proposed Yucca Mountain Repository include an estimate of dose to the reasonably maximally exposed individual. The Rule further states that this assessment provide, for 10,000 years, the reasonably maximally exposed individual annual committed effective dose equivalent (40 CFR 197.20 and 197.25). For the purposes of this EIS, the analysis of long-term performance must calculate the peak dose that would occur within the period of geologic stability (40 CFR 197.35). The peak dose is projected to occur within 1,000,000 years.

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The methodology used for the calculations presented in this EIS draws upon the extensive analyses carried out in support of the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, all) and in the *FY01 Supplemental Science and Performance Analyses,* Volumes 1 and 2 (DIRS 155950-BSC 2001, all, and DIRS 154659-BSC 2001, all). Only those model components and related parameters that were modified to account for the scenarios considered in addition to those used in the TSPA–Site Recommendation or the *FY01 Supplemental Science and Performance Analyses* are described in this EIS. In addition, the model configuration used for the calculations presented in this EIS was modified to conform to the recently promulgated U.S. Environmental Protection Agency Final Rule. The Final Rule provides the criteria to be used in determining the RMEI location [40 CFR 197.21(a)], the other criteria of the RMEI (that were applied in the calculation of biosphere dose-conversion factors), and the groundwater protection standard, including the representative volume to be used for the calculation of gross alpha activity, total radium activity, and whole-body dose (40 CFR 197.30, Table 1). These modifications are described in Section I.4.4.

This EIS considers inventories in addition to those described in the TSPA–Site Recommendation and the *Supplemental Science Performance Analyses* for the 70,000 MTHM inventory. The calculations in this EIS include the Proposed Action (70,000 MTHM inventory) under both the higher-temperature repository operating mode and lower-temperature operating mode, and the Module 1 and 2 inventories under the higher-temperature operating mode, for the following scenarios:

- The nominal scenario that considers performance of the repository under undisturbed conditions, but including seismic activity.

- The human intrusion scenario (DIRS 153246-CRWMS M&O 2000, Section 4.4, pp. 4-25 to 4-32), that considers an “intruder” drilling a land-surface borehole using a drilling apparatus (under the common techniques and practices currently employed in exploratory drilling for groundwater in the region around Yucca Mountain), drilling directly through an intact or degraded waste package, and subsequently into the uppermost aquifer underlying Yucca Mountain. The intrusion then causes the subsequent compromise and release of contaminated material in the waste package. The human-intrusion scenario was simulated for a 1-million year performance period with the intrusion at 30,000 years after repository closure.

- The igneous activity scenario contains two separate possible events: a volcanic eruption that includes exposure as a result of atmospheric transport and deposition on the ground, and an igneous intrusion groundwater transport event (DIRS 155950-BSC 2001, Section 14.2.1, p. 14-5). In the volcanic eruption event (DIRS 153246-CRWMS M&O 2000, Section 3.10, pp. 3-187 to 3-216), a dike (or dikes) would intersect the repository and compromise all waste packages in the conduit. Then, an eruptive conduit of an associated volcano would intersect waste packages in its path. Waste packages in the path of the conduit would be sufficiently damaged that they provide no further protection, and the waste in the packages would be entrained in the eruption and subject to atmospheric transport. In the igneous intrusion groundwater transport event, the analysis calculated releases caused by a dike (or dikes) intersecting emplacement drifts, causing varying degrees of waste-package damage.

I.4.2 ASSUMPTIONS

This section identifies assumptions that are essential for this calculation. The assumptions listed here contribute to the generation of results reported in Sections I.5 and I.6 of this appendix.

1. The Proposed Action (70,000-MTHM) model configuration for the calculations in this EIS consists of the *FY01 Supplemental Science and Performance Analyses* model (DIRS 155950-BSC 2001, all), which differs from the TSPA–Site Recommendation model (DIRS 153246-CRWMS M&O 2000, all).

The model used for the calculations in Sections I.5 below includes the modifications from the Supplemental Science and Performance Analyses and TSPA–Site Recommendation models as described below in Section I.4.4. Other assumptions incorporated into the Supplemental Science and Performance Analyses model are documented in the *FY01 Supplemental Science and Performance Analyses* Volume 2 (DIRS 154659-BSC 2001, Section 2, all). The key differences between the Supplemental Science and Performance Analyses and the model configuration used in the calculations presented in this EIS are described in Section I.4.4.

2. The radionuclide inventories used in the calculations in Section I.5 are those developed in the *Inventory Abstraction* Analysis Model Report (DIRS 154841-BSC 2001, Table 36, p. 38). The per-waste-package inventories for commercial spent nuclear fuel and codisposal waste packages are the same as those used in the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, Section 3.5.1, pp. 3-94 to 3-100), but the DOE-owned spent nuclear fuel inventory does not include naval spent nuclear fuel. The naval spent nuclear fuel is conservatively represented by commercial spent nuclear fuel (DIRS 152059-BSC 2001, all, and DIRS 153849-DOE 2001, Section 4.2.6.3.9, p. 4-257). The per-waste-package inventories used for the Greater-Than-Class-C calculations use the Greater-Than-Class-C inventory presented in Attachment VI of the *EIS Performance–Assessment Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain* (DIRS 155393-CRWMS M&O 2000, p. VI-5) divided according to the number of packages indicated in DIRS 155393-CRWMS M&O (2000, Attachment VI).

I.4.3 USE OF COMPUTER SOFTWARE AND MODELS

The calculations described in this EIS were performed using the numerical code GoldSim, Version 7.17.200 (DIRS 155182-BSC 2001, all). GoldSim was developed by Golder Associates as an update to the baseline software RIP v.5.19.01 (DIRS 151395-Golder Associates 1998, all). GoldSim is an object-oriented program that is computationally similar to RIP v.5.19.01, which was used for the TSPA–Viability Assessment (DIRS 101779-DOE 1998, Volume 3, p. 2-29). GoldSim is designed such that probabilistic simulations can be conducted and represented graphically.

I.4.4 MODIFICATIONS TO THE TSPA–SITE RECOMMENDATION AND SUPPLEMENTAL SCIENCE AND PERFORMANCE ANALYSIS MODELS

This EIS builds on the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, all) and *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, all) modeling of the Proposed Action (70,000-MTHM) repository configuration. Because this EIS evaluates the possible consequences of ultimately including the entire commercial spent nuclear fuel, DOE-owned spent nuclear fuel, and high-level radioactive waste inventories, an expanded repository area was also considered.

The change from the TSPA–Site Recommendation waste inventory and repository area to a calculation of the performance of an expanded repository includes addition of the Lower Block, shown on Figure I-3, in the calculations. The TSPA–Site Recommendation and Supplemental Science and Performance Analyses reports relied only on a detailed analysis of just the Primary Block shown on Figure I-3.

The GoldSim numerical code simulates transport of radionuclides from the repository, through the unsaturated zone, and through the saturated zone to the accessible environment. The different process models included in the GoldSim code are fully described and documented in the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, all). The unsaturated zone transport release nodes and saturated zone transport capture areas for the 70,000-MTHM inventory in the TSPA–Site Recommendation and Supplemental Science and Performance Assessment models were modified for Inventory Modules 1 and 2 to include the Lower Block emplacement area (DIRS 157307-BSC 2001, all).

The GoldSim model configuration used for the Supplemental Science and Performance Analyses was modified to conform to the recently published Environmental Protection Agency Final Rule 40 CFR Part 197. The model also assesses the performance of additional radionuclide inventories and performance scenarios. Sections I.4.4.1 through I.4.4.8 describe the modifications to the TSPA–Site Recommendation and Supplemental Science and Performance Analyses models. The model configuration for the calculations in this EIS differs from earlier performance assessment models in the following areas:

- The model used for the calculations in this EIS used biosphere dose conversion factor based on the RMEI defined in 40 CFR 197.21. The models used in the TSPA–Site Recommendation and Supplemental Science and Performance Analyses used different biosphere dose conversion factors based on the average member of the critical group in the then-proposed 10 CFR 63.115.

- The length of the saturated zone simulated in the model configuration for the calculations in this EIS extends from inside the repository footprint to latitude 36 degrees 40 minutes 13.6661 seconds north, above the highest concentration of radionuclides in the plume of contamination. The RMEI is assumed to reside at this location in the accessible environment. The latitude at this location is at the southwestern corner of the Nevada Test Site.

- Groundwater protection was assessed using an annual representative volume of 3.7 million cubic feet (exactly 3,000 acre-feet) per year of groundwater, as specified at 40 CFR Part 197, to calculate the total alpha activity, the total radium concentration, and the whole-body dose. To calculate all other concentrations not included in the groundwater-protection standard, the water usage was assigned in the same probabilistic manner used in the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, Section 3.9.2.4, p. 3-184) and the *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, Section 13.3.5, pp. 13-41 to 13-44).

- The waste inventories used for the calculations in this EIS are presented in DIRS 154841-BSC (2001, Table 36, p. 38).

- Waste-package corrosion for the calculations in this EIS would be due to general corrosion independent of temperature, as was true for the TSPA–Site Recommendation. The Supplemental Science and Performance Analyses calculations included temperature-dependent waste package corrosion.

- The process-level lower-temperature operating mode thermal-hydrologic results for this EIS were corrected from those presented in the Supplemental Science and Performance Analyses to include radiative heat transfer in the unsaturated zone modeling with the Nonisothermal Unsaturated-Saturated Flow and Transport model.

I.4.4.1 Modifications to FEHM Particle Tracker Input and Output

The unsaturated zone flow-and-transport modeling in the TSPA–Site Recommendation, in the *FY01 Supplemental Science and Performance Analyses*, and in this EIS are conducted with the Finite Element Heat and Mass (FEHM) model. The movement of fluid and radionuclides released from the waste packages was modeled in the unsaturated zone by means of a particle-tracking algorithm in the TSPA–Site Recommendation and Supplemental Science and Performance Analyses process models (DIRS 153246-CRWMS M&O 2000, p. 2-27; DIRS 155950-BSC 2001, Section 11). The particle-tracking files used in the TSPA–Site Recommendation were modified for the increased inventories of Modules 1 and 2 to allow the FEHM unsaturated zone input regions to correspond to the Lower Block area used for the simulations. The interface file in GoldSim was modified for this case by changing the FEHM nodes used for transport from the Primary Block as considered in the TSPA–Site Recommendation and the Supplemental Science and Performance Analyses for the Proposed Action inventory. The calculations presented in this EIS also include the Lower Block of a potential repository that would also be used for input of mass from an expanded repository area. The FEHM nodes were chosen to correspond to the Lower Block repository coordinates because of the changes to the regions from where mass is captured coming out of the FEHM model (DIRS 155393-CRWMS M&O 2000, Attachments II and III). Capture regions at the surface of the saturated zone would accumulate water and mass released from the repository that had been transported through the unsaturated zone. The capture regions for the Primary Block are shown in Figure I-4. These capture regions were modified to ensure all the mass would be captured and to distribute the mass to the saturated zone capture regions, including release from the Lower Block. Figure I-5 shows the capture regions used for Inventory Modules 1 and 2.

The repository nodes were extracted based on the information and representation of the repository configuration described in *EIS Performance-Assessment Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain* (DIRS 155393-CRWMS M&O 2000, Attachment II). The drifts in the Lower Block were first aggregated into larger groups based on similar elevations. Then the boundary coordinates of the larger groups were used to define rectangular regions. The Software Routine *repocoord1.f* (Version 1.0) (DIRS 155393-CRWMS M&O 2000, Attachment II) was used to extract FEHM nodes within the rectangular region. The extracted nodes were then plotted using SigmaPlot (Version 4.01, a commercial graphics software package) and nodes that fell beyond the defined drift region were removed from the repository node list. The use of *repocoord1.f* (Version 1.0) in these EIS calculations is documented in DIRS 155393-CRWMS M&O (2000, Attachment II).

I.4.4.2 Estimation of the Thermal Profiles and Infiltration for the Lower Block

The TSPA–Site Recommendation and *FY01 Supplemental Science and Performance Analyses* models used to assess repository performance utilized thermal-hydrologic modeling to estimate infiltration from land surface to the repository horizon. Infiltration water would be the principal cause of waste-package corrosion and the main agent for waste transport. The TSPA–Site Recommendation and *FY01 Supplemental Science and Performance Analyses* model conceptualizations for the Yucca Mountain Repository would be considered waste forms in discrete areal regions of the repository as source terms for flow and transport from the repository to the saturated zone. The GoldSim conceptualization for the TSPA–Site Recommendation considered the repository block, referred to as the Primary Block, to be comprised of four source regions (Figure I-4). The four regions are covered by the Yucca Mountain multiscale thermohydrologic model and its abstraction, which was used to develop the thermodynamic-environment time histories at different potential waste-package locations distributed throughout the Primary Block (DIRS 139610-CRWMS M&O 2000, Section 6.6, all; DIRS 154594-CRWMS M&O 2001, Section 6.3). These time histories for the higher-temperature operating mode were used in both the TSPA–Site Recommendation and the *FY01 Supplemental Science and Performance Analyses*.

The calculations for Inventory Modules 1 and 2 for this EIS used two additional areas for disposal, using an additional approximately 0.88 square kilometer (218 acres) of the Primary Block that was not used in the design of the Primary Block for the Proposed Action, the higher-temperature operating mode (DIRS 150941-CRWMS M&O 2000, Figure 4-14), and approximately 1.7 square kilometers (408 acres) of the Lower Block, which would be to the east of the Primary Block (Figure I-3). For Inventory Modules 1 and 2, source region 2 was expanded to the east so that its areal extent would include the Lower Block (Figure I-5) (DIRS 155393-CRWMS M&O 2000, Section 5.2.2, p. 11-12).

The following methodology was used to develop thermal histories for waste packages emplaced in the Lower Block. The thermal response from the multiscale thermohydrologic model (DIRS

149862-CRWMS M&O 2000, all) is correlated to the distance from the edge of the repository. Further, seepage into the drift would be a function of the local infiltration flux. Therefore, the location and estimated infiltration flux were used to select analogous Primary Block thermal-hydrologic responses for application to comparable locations in the Lower Block. Thus, the Primary Block thermal-hydrologic data were extended to the 51 Lower Block elements shown on Figure I-6. It should be noted that DOE would pursue a comprehensive characterization of these blocks before it used them for waste emplacement. The modeling work described in this EIS related to these uncharacterized blocks is limited to estimating the environmental impacts under the expanded inventory (Modules 1 and 2) configuration. The detail on extending this method to the 51 nodes is in DIRS 155393-CRWMS M&O (2000, Attachment II, pp. II-2 to II-5), and the estimation of lower-block infiltration seepage rates is in DIRS 155393-CRWMS M&O (2000, Attachment III, pp. III-2 to III-19). The glacial-transition climate infiltration rate for the 51 elements was estimated from the site-scale hydrologic model (DIRS 100103-Bodvarsson, Bandurraga, and Wu 1997, all). For each of the 51 Lower Block elements, the GoldSim code was configured with thermal history data sets from the site multiscale thermohydrologic model (DIRS 139610-CRWMS M&O 2000, Section 6.6, all, and its abstractions; DIRS 154594-CRWMS M&O 2001, Section 6.3) based on similar infiltration and proximity to the edge of the repository as the analogous Primary Block locations. Using these data, the infiltration categories, or bins, for the waste packages associated with the Inventory Modules 1 and 2 cases were established as described in Attachment IV of the calculation document *EIS Performance-Assessment Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain* (DIRS 155393-CRWMS M&O 2000, pp. IV-2 to IV-4). The use of thermal profiles in estimating infiltration to the repository blocks is described in detail in Attachment III of the calculation document *EIS Performance-Assessment Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain* (DIRS 155393-CRWMS M&O 2000, pp. III-2 to III-19). DIRS 157307-BSC (2001, Attachment II) describes the calculation of the fractional Lower Block repository areas corresponding to the infiltration bins for these calculations.

I.4.4.3 Saturated Zone Breakthrough Curves

Transport in the saturated zone beneath the repository would be the main route for groundwater transport of contaminants leached from the repository. The radioactive contaminants would move through the saturated zone to the accessible environment. The accessible environment is defined as any area outside the controlled area (40 CFR 197.12). The Environmental Protection Agency Final Rule (40 CFR 197.12) specifies the following elements of the controlled area:

1. The surface area, identified by passive institutional controls, that encompasses no more than 300 square kilometers (about 74 acres). It must not extend farther:

    a. South than 36 degrees 40 minutes 13.6661 seconds north latitude, in the predominant direction of groundwater flow; and

    b. Than 5 kilometers (3 miles) from the repository footprint in any other direction; and

2. The subsurface underlying the surface area.

The location where the RMEI would reside, where groundwater protection was analyzed, would be the point above the highest concentration of radionuclides in the simulated plume of saturated zone contamination where the plume crossed the southernmost boundary of the controlled area (at a latitude of 36 degrees 40 minutes 13.6661 seconds North) and reached the accessible environment. For this analysis, DOE selected the southern boundary of the controlled area and the location of the RMEI to be at the limit discussed above, which is approximately 18 kilometers (11 miles) from the potential repository, compared to the corresponding distance of approximately 20 kilometers (12 miles) used in the saturated zone transport modeling for TSPA–Site Recommendation and the *FY01 Supplemental Science and*

Performance Analyses, as shown in Figure I-7. To analyze long-term performance with respect to the standard set in the Environmental Protection Agency Final Rule 40 CFR 197.12, additional saturated zone breakthrough curves, which describe the time-related arrivals of radionuclides at the RMEI location, were calculated for all radionuclides used in the calculations in this EIS. The saturated zone breakthrough curves were used in the analyses to simulate radionuclide transport from the water table beneath the proposed repository to the receptor location. Depending on the subsurface layout of a repository, the distance to the RMEI location from any point in the subsurface layout could be more or less than 18 kilometers. For convenience and consistency with other documents, the RMEI location is consistently discussed as being approximately 18 kilometers (11 miles) downgradient from the proposed repository.

To generate the saturated zone breakthrough curves used in the calculations in this EIS, 100 realizations of the saturated zone site-scale flow-and-transport model were performed as described for the saturated zone process model (DIRS 139440-CRWMS M&O 2000, Sections 6.2 and 6.3) to generate saturated zone breakthrough curves at the RMEI location. Other stochastic parameters for the saturated zone simulations use the same values as those used in the saturated zone breakthrough curves for the *FY01 Supplemental Science and Performance Analyses* (DIRS 154659-BSC 2001, Section 3.2.10). The simulated radionuclide breakthrough curves at the RMEI location exhibited shorter transport times than those at 20 kilometers (12 miles), as presented in *Supplemental Sciences and Performance Analyses* (DIRS 155950-BSC 2001, Section 13.2.1.3) on a realization-by-realization basis. In particular, radionuclides that could have significantly greater sorption in the alluvium than in the volcanic units (such as neptunium-237) exhibited shorter transport times to the RMEI location in this analysis relative to the 20-kilometer location used in the TSPA–Site Recommendation, the *Supplemental Science Performance Analyses*, and in the Draft EIS. This result is related to the fact that the RMEI location in this analysis would result in a decrease in the length of transport through the alluvium relative to the transport path to the 20-kilometer location.

The approach used for simulations of groundwater flow and radionuclide transport in the saturated zone used in this EIS is the same as the approach used in the TSPA–Site Recommendation. The saturated zone site-scale flow-and-transport model was used to simulate the unit radionuclide mass breakthrough curves for radionuclides of concern to the Site Recommendation at the RMEI location. In the model configuration for the calculations for this EIS, these saturated zone breakthrough curves are coupled with the other components of the system (mass flux and representative volume or water usage) using the convolution-integral method in the same manner as described and implemented in the GoldSim program for the TSPA–Site Recommendation and the *FY01 Supplemental Science and Performance Analyses* (DIRS 153246-CRWMS M&O 2000, Section 2.2.2; DIRS 155950-BSC 2001, Section 3.2.10). In addition, the simulation of radionuclide decay chains and the transport of decay products in the saturated zone system was performed using a one-dimensional model directly in the GoldSim numerical code.

In the saturated zone model, the capture regions that would accumulate flow and mass at the base of the unsaturated zone become the source regions for the saturated zone model. The four radionuclide source regions in the saturated zone (Figures I-4 and I-5) that were defined for the 70,000-MTHM case of the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, Section 3.8.2.2 and Figure 3.8-14, p. F3-117) were used in the calculations in this EIS. For Inventory Modules 1 and 2, radionuclide mass originating from the Lower Block of the repository is applied to source region number 2 in the saturated zone transport module. The Lower Block of the expanded repository would extend farther to the east than the saturated zone source region number 2 for the TSPA–Site Recommendation base case. However, applying the radionuclide mass from the Lower Block to this source region constitutes a conservative approximation of transport in the saturated zone. Lower permeability rocks of the upper volcanic confining unit exist at the water table in the area immediately to the east of saturated zone source region number 2, which would result in slower initial advective groundwater velocity for radionuclide transport in this area. Preliminary results of radionuclide transport simulations with the saturated zone site-scale flow and transport model confirm that radionuclide transport times in the saturated zone from the area below the Lower Block would be longer than the transport times from saturated zone source region number 2 in the Proposed Action considered in this EIS.

I.4.4.4 Modification to the Waste Package Degradation Model

The WAste Package DEGradation (WAPDEG) model (DIRS 151566-CRWMS M&O 2000, all) was used to calculate drip shield and waste package degradation profiles with time in the GoldSim TSPA model configurations used for TSPA–Site Recommendation, *FY01 Supplemental Science and Performance Analyses*, and this EIS. Several input parameters to the WAPDEG model developed for TSPA–Site Recommendation (DIRS 151566-CRWMS M&O 2000, all) were reevaluated in the *FY01 Supplemental Science and Performance Analyses*, Volume 1 (DIRS 155950-BSC 2001, Section 7). The reevaluation led to the following changes to the TSPA–Site Recommendation WAPDEG model and parameters used in the *FY01 Supplemental Science and Performance Analyses* and the calculations in this EIS. These changes are described in detail in *FY01 Supplemental Science and Performance Analyses*, Volume 1 (DIRS 155950-BSC 2001, Section 7) and are summarized here:

- All surface-breaking weld flaws and all weld flaws embedded in the outer one quarter of the closure weld thickness were considered capable of propagation in the radial direction in the WAPDEG model developed for the TSPA–Site Recommendation (DIRS 151566-CRWMS M&O 2000, Section 5.5, p. 39). In the *FY01 Supplemental Science and Performance Analyses* and in this analysis, the fraction of these weld flaws capable of propagation in the radial direction is given by a ±3 standard deviation truncated lognormal distribution with a mean of 0.01 and bounded between 0.5 (+3 standard deviations) and 0.0002 (-3 standard deviations) (DIRS 155950-BSC 2001, Section 7.3.3.3.4, p. 7-41).

- The stress threshold for the initiation of stress corrosion cracking was given by a uniform distribution between 20 and 30 percent of the Alloy-22 yield strength in the WAPDEG model developed for the TSPA–Site Recommendation (DIRS 151566-CRWMS M&O 2000, Section 4.1.9, p. 29). In the *FY01 Supplemental Science and Performance Analyses* and for this analysis, the stress threshold for the initiation of stress corrosion cracking is given by a uniform distribution between 80 and 90 percent of the Alloy 22 yield strength (DIRS 155950-BSC 2001, Section 7.3.3.3.3, p. 7-39).

- The uncertainty bounds of the residual stress profile in the Alloy-22 waste package outer closure lid weld regions (induction annealed) were set to ±30 percent of the yield strength of Alloy-22 in the WAPDEG Model developed for TSPA–Site Recommendation (DIRS 151566-CRWMS M&O 2000, Section 6.5.1, p. 79). In the *FY01 Supplemental Science and Performance Analyses* and in this analysis, the uncertainty bounds of the residual stress profile in the Alloy-22 waste package outer closure lid weld regions were set to ±21.4 percent of the yield strength (DIRS 155950-BSC 2001, Section 7.3.3.3.1, p. 7-74).

- The uncertainty bounds of the residual stress profile in the Alloy-22 waste package inner closure lid weld regions (laser peened) were set to ±30 percent of the yield strength of Alloy-22 in the WAPDEG model developed for TSPA–Site Recommendation (DIRS 151566-CRWMS M&O 2000, Section 6.5.1, p. 79). In the *FY01 Supplemental Science and Performance Analyses* and in this analysis, the uncertainty bounds of the residual stress profile in the Alloy-22 waste package inner closure lid weld regions were sampled from a cumulative distribution function (DIRS 155950-BSC 2001, Section 7.3.3.3.2, p. 7-37 and Table 7.3.3-2, p. 7T-4).

- The variances of the general corrosion rate distributions for Alloy-22 and titanium Grade 7 were considered to result from contributions of both uncertainty and variability in the WAPDEG model developed for the TSPA–Site Recommendation (DIRS 151566-CRWMS M&O 2000, Section 6.3.1, p. 55). In *FY01 Supplemental Science and Performance Analyses* and in this analysis, the total variance of the general corrosion rate distributions was treated as uncertainty (DIRS 155950-BSC

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2001, Section 7.3.5.2, p. 7-54). To ensure conservatism in the analysis, the temperature-dependent Alloy-22 general corrosion model developed for the *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, Section 7.3.5.3.2, p. 7-56) was not used in this analysis. This is conservative because the non-temperature-dependent model uses a high bounding rate characteristic of high temperature, while the temperature-dependent model would take credit for long periods of lower temperatures and corresponding low corrosion rates. The same Alloy-22 and titanium Grade 7 general corrosion rate distributions used in the WAPDEG model developed for TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000. Section 3.4.1, pp. 3-80 to 3-87) and the *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, Section 7.3.5, pp. 7-52 to 7-61) were also used in the calculations in this EIS. The calculated means of the general corrosion rate distribution used for the calculations in this EIS are 1.94×10^{-4} millimeter (7.64×10^{-6} inch) per year for titanium Grade 7 and 6.80×10^{-5} millimeter (2.68×10^{-6} inch) per year for Alloy-22. The data used to calculate the means are from complementary distribution functions in *WAPDEG Analysis of Waste Package and Drip Shield Degradation* (DIRS 151566-CRWMS M&O 2000, Section 4, pp. 19 and 20).

I.4.4.5 Early Waste Package Failure

The potential waste package early failure mechanisms were reevaluated in the *FY01 Supplemental Science and Performance Analyses*, particularly improper heat treatment of waste packages (DIRS 155950-BSC 2001, Section 7.3.6, p. 7-62). These results are incorporated in the calculations in this EIS. The probability of having one or more waste packages in the repository improperly heat-treated is provided in Table I-3.

In evaluating the potential consequences of early failures by improper heat treatment for the *FY01 Supplemental Science and Performance Analyses* and this EIS, early waste-package failure would occur on initiation of corrosive processes and would be due to failure of the outer and inner closure lids of the waste package outer barrier and the failure of the closure lid of the stainless-steel structural waste package inner shell. Details of the use of this model in performance assessment analyses are discussed in *FY01 Supplemental Science and Performance Analyses*, Volume 2 (DIRS 154659-BSC 2001, Section 3.2.5.4, p. 3-21). The following elements were employed in that evaluation:

1. Those waste packages affected by early waste-package failure would fail immediately by general corrosion as patches (DIRS 154659-BSC 2001, Section 3.2.5.4, p. 3-21).

2. The area on the waste package affected by improper heat treatment would be equal to the area of closure-weld patches because improper heat treatment would be most likely to occur during the induction annealing of the outer closure lid welds of the waste-package outer barrier.

3. The materials of the entire affected area would be lost on failure of the waste packages because the affected area would be subject to stress-corrosion cracking and highly enhanced localized and general corrosion.

4. The weld region of the inner closure lid of the outer barrier and the closure lid of the stainless-steel structural inner shell would fail at the same time the outer closure-lid weld region failed.

These assumptions are conservative because only the weld region of the outer lid of the outer barrier would be affected by potential improper heat treatment during the stress mitigation heat treatment (induction annealing), and the inner lid of the outer barrier would be unlikely to be affected. In a more realistic scenario, the breached weld patches of the affected waste package would remain with the waste package until the weakened areas were affected by a major mechanical impact or corroded away by general corrosion.

I.4.4.6 Biosphere Dose Conversion Factors for the 40 CFR 197 Reasonably Maximally Exposed Individual

Biosphere dose conversion factors were used to estimate the radiation dose that would be incurred by an individual when a unit activity concentration of a radionuclide reached the accessible environment. The biosphere dose conversion factors for the RMEI were developed using the environmental and agricultural parameters characteristic of the Amargosa Valley region, and the dietary and lifestyle characteristics of the RMEI consistent with those specified in 40 CFR 197.21. The lifestyle characteristics of the RMEI were representative of a rural-residential population. The dietary characteristics of the RMEI were based on a food consumption survey (DIRS 100332-DOE 1997, all) for the population of the town of Amargosa Valley, Nevada. Consistent with the final rule at 40 CFR 197.21, the dietary characteristics of the RMEI were represented by the mean values of locally produced food for Amargosa Valley residents. The dietary and lifestyle attributes of the RMEI are listed in Table I-10. The dietary attributes were developed using the set of recently reevaluated and updated values of consumption rates of locally produced food in *Calculation: Consumption Rates of Locally Produced Food in Nye and Lincoln Counties* (DIRS 156016-BSC 2001, all). This set of consumption rates is different from the set used in the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, Section 3.9) and the *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, Section 13) analyses. The changes include the update of the contingent average daily intakes of food, adjustments in the grouping of the food categories, and adjustments in the selection of individuals whose consumption rates were used to develop the RMEI.

Table I-10. Average values of the dietary and lifestyle attributes for the RMEI.

Parameter	Mean value of the attribute
Leafy vegetables consumption rate (kilograms[a] per year)	3.9
Other vegetables consumption rate (kilograms per year)	4.8
Fruit consumption rate (kilograms per year)	12.4
Grain consumption rate (kilograms per year)	0.3
Meat consumption rate (kilograms per year)	2.6
Poultry consumption rate (kilograms per year)	0.4
Milk consumption rate (liters[b] per year)	4.8
Eggs consumption rate (kilograms per year)	5.6
Fish consumption rate (kilograms per year)	0.3
Water consumption rate (liters per year)	730
Inadvertent soil ingestion (milligrams[c] per day)	50
Inhalation exposure time (hours)	5,073.5
Soil exposure time (hours)	2,387

a. To convert kilograms to pounds, multiply by 2.2046.
b. To convert liters to gallons, multiply by 0.26417.
c. To convert milligrams to ounces, multiply by 0.000035274.

The biosphere dose conversion factors for the RMEI, characterized by the set of attributes listed in Table I-10, are given in Table I-11.

I.4.4.7 Igneous Activity Scenario

The model and parameter changes from TSPA–Site Recommendation to the model configuration used in the analysis for this EIS for the igneous activity scenario are described in detail in *FY01 Supplemental Science and Performance Analyses*, Volume 1 (DIRS 155950-BSC 2001, Sections 13 and 14) and are summarized here.

Several input parameters to the TSPA models used to calculate consequences of igneous disruption changed after the TSPA–Site Recommendation and have been included in this analysis (DIRS 155950-

Table I-11. Biosphere dose conversion factors for the RMEI for the groundwater release and the volcanic release exposure scenarios.

Radionuclide	Groundwater release[a] (rem per picocurie per liter[b])	Volcanic release[a] (rem per picocurie per square meter[c])
Carbon-14	0.000029	NA[d]
Selenium-79	0.000012	3.8×10^{-11}
Strontium-90	0.0002	4.2×10^{-9}
Technetium-99	0.0000028	NA
Iodine-129	0.00025	NA
Cesium-137	0.00034	1.2×10^{-9}
Lead-210	0.0051	1.4×10^{-8}
Radium-226	0.005	4.2×10^{-9}
Actinium-227	0.013	1.9×10^{-6}
Thorium-229	0.0061	6.0×10^{-7}
Thorium-230	0.0012	9.1×10^{-8}
Protactinium-231	0.016	3.8×10^{-7}
Uranium-232	0.0018	1.9×10^{-7}
Uranium-233	0.00028	3.8×10^{-8}
Uranium-234	0.00027	3.8×10^{-8}
Uranium-236	0.00026	NA
Uranium-238	0.00026	NA
Neptunium-237	0.0045	1.9×10^{-7}
Plutonium -238	0.0029	1.1×10^{-7}
Plutonium-239	0.0035	1.3×10^{-7}
Plutonium -240	0.0035	1.3×10^{-7}
Plutonium-242	0.0032	1.2×10^{-7}
Americium-241	0.0035	1.3×10^{-7}
Americium-243	0.004	1.3×10^{-7}

a. Biosphere Dose Conversion Factors for the transition phase, 1 centimeter (0.4 inch) layer of ash and annual average mass loading
b. To convert liters to gallons, multiply by 0.26417.
c. To convert from square meters to square feet, multiply by 10.764.
d. NA = not applicable.

BSC 2001, Section 14.3.3.7). Consistent with new information regarding the probability of an eruption at the location of the proposed repository given an igneous intrusive event (DIRS 155950-BSC 2001, Section 14.3, all), the conditional probability of an eruption at the proposed repository was revised from 0.36 (DIRS 153246-CRWMS M&O 2000, Table 3.10-4, p. 198) to 0.77 (DIRS 155950-BSC 2001, Section 14.3.3.1, p. 14-13). According to *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (DIRS 151551-CRWMS M&O 2000, Section 6.5.3.2, and Table 12a, p. 130), the approach for the calculation of the conditional number of eruptive centers occurring within the repository footprint was modified by: 1) using empirical distributions for the average spacing between eruptive centers rather than the expected values for these distributions, and 2) incorporating uncertainty in the effect of the repository opening on the conditional probability of the occurrence of an eruptive center within the repository footprint. This modified approach resulted in the new conditional probability of 0.77 for one eruptive center to occur involving the Primary Block of the higher-temperature repository operating mode footprint during or coincident with an igneous activity event. This conditional probability has also been assumed for the lower-temperature operating mode analyses in Section I.5.

Changes also were made in the probability distribution for an intrusive event, consistent with revisions in the repository footprint (changes related to the higher-temperature operating mode) because inputs were compiled for TSPA–Site Recommendation. Revised distributions were provided for the number of waste packages affected by igneous intrusion and volcanic eruption events, consistent with the revised event probability information for the Primary Block of the higher-temperature operating mode. This adjusted event probability has also been assumed for the lower-temperature operating mode analyses in Section I.5. Changes have been made in the input data used to determine the wind speed during an eruption (DIRS 155950-BSC 2001, Section 3.3.1.2.1). Additional changes in inputs to the TSPA–Site Recommendation igneous consequence model are listed in *FY01 Supplemental Science and Performance Analyses*, Volume 1 (DIRS 155950-BSC 2001, Section 14.3.3.7, p. 14-24, and Tables 14.3.3.7-1 and 14.3.3.7-2, p. 14T-5 to 14T-6). Other model inputs and assumptions, including the assumption that wind direction would be fixed toward the location of the exposed individual at all times, were the same as those used in the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, Section 3.10).

I.4.4.8 Human Intrusion Scenario

The human intrusion scenario for the calculations in this EIS was developed from that in the TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, Section 4.4). The model changes implemented for the human intrusion calculations in this EIS are described in this section.

Errata in the TSPA–Site Recommendation human intrusion model associated with "boosting" the inventory of certain radionuclides to account for first-generation decay product transport through the three-dimensional saturated zone model (DIRS 148384-CRWMS M&O 2000, Section 6.3.4.1, p. 233) were corrected.

In the TSPA–Site Recommendation human intrusion submodel (DIRS 148384-CRWMS M&O 2000, Section 6.3.9.3, p. 513), for the purpose of determining thermal-hydrologic conditions, in-package chemistry, and in-drift chemistry, the failed waste package was placed in a specified dripping environment for a given infiltration condition. For the calculations in this EIS, the failed waste package for each realization of the human intrusion scenario was randomly placed in one of several dripping environments depending on the infiltration condition.

Colloidal-facilitated transport of americium, plutonium, thorium, and protactinium in an exploratory borehole through the unsaturated zone has been included in the human intrusion scenario in this EIS. The decay products of irreversibly sorbed americium-241 and neptunium-237 were included as an irreversibly sorbed colloidal species. Colloidal-facilitated transport was implemented by adjusting the sorption coefficients of the aforementioned nuclides according to the relationship (DIRS 139440-CRWMS M&O 2000, p. 26):

$$K_d^{adj} = \frac{K_d^{orig}}{1 + K_c}$$

where

K_d^{orig} = sorption coefficient without colloidal-facilitated transport

K_d^{adj} = sorption coefficient with colloidal-facilitated transport

K_c = colloid partition coefficient

The human intrusion scenario in this EIS was simulated for a 1-million-year duration (as opposed to the 100,000-year duration in the TSPA–Site Recommendation). To be consistent with the *FY01 Supplemental Science and Performance Analyses* 1-million-year calculations, two additional radionuclides, radon-228 and thorium-232, were included in the inventory (DIRS 155950-BSC 2001, Section 13.2.1.10, pp. 13-9 and 13-10). The 30,000-year human intrusion scenario is the same scenario analyzed in the *FY01 Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, Volume 1, Appendix A). The information in that appendix addresses the issue of when a human intrusion could occur based upon the earliest time that current technology and practices could lead to waste package penetration without the driller noticing waste package penetration. The earliest time would be that time (approximately 30,000 years) when the waste package had corroded sufficiently that a drill bit could penetrate it.

The assessment of the human intrusion scenario did not combine the results of this scenario with the results of the disruptive igneous activity scenario. However, combined results can be approximated by adding the results of the human intrusion calculations to the results of the disruptive igneous event scenario. Based on the results in Section I.5, the highest mean annual individual dose that would result from a human intrusion would be less than one-tenth of the radiological dose from a disruptive igneous event.

I.4.5 EXTENSION OF GROUNDWATER IMPACTS TO OTHER DISTANCES

The TSPA model described in Section I.2 was used to model the environmental impacts to groundwater for the long-term postclosure period. The TSPA model was originally developed to support the Yucca Mountain site suitability evaluation and possible subsequent licensing compliance analyses for the repository if the site was recommended. The model is, therefore, focused on the compliance requirements set forth in applicable regulations such as the Environmental Protection Agency standard, 40 CFR Part 197. This standard is concerned with a single compliance point, the RMEI location. The long-term impacts to groundwater predicted by the TSPA model would be restricted to that single location. Supporting models, such as the site-scale flow and transport model, were developed to support the TSPA calculation and do not extend much beyond the RMEI location. Furthermore, the TSPA made a conservative assumption that all radionuclide mass in groundwater would be captured in the water usage at the RMEI location. This is a reasonable approach for the compliance calculations because it tends to bias the concentration of materials to a higher value, without trying to account for complicated plume-capture considerations, and also because the volume of the plume passing this point in 1 year would be on the order of the upper bound of water usage. However, this assumption in the model does not allow it to account for the spreading of the plume at greater distances considered in this EIS.

As part of a comprehensive presentation of impacts, this EIS is charged with providing groundwater impacts for two other important downgradient locations. These are 30 kilometers (18 miles), where most of the current population in the groundwater path is located, and 60 kilometers (37 miles), where the aquifer discharges to the surface (also known as Franklin Lake Playa). The selection of these locations is discussed in Section I.4.5.1.

To provide insight about impacts at these other distances, a method of scaling was developed. This was necessary because the TSPA model is limited to the RMEI location, as described above. This section describes the approach to the scaling and the results obtained. The scaling approach is discussed in Section I.4.5.2 and the scaling factors in Section I.4.5.3.

I.4.5.1 Locations for Assessing Postclosure Impacts to Human Health

The Environmental Protection Agency public health and environmental radiation protection standards for Yucca Mountain (40 CFR Part 197) require DOE to estimate the potential radiation doses to the public from the disposal of spent nuclear fuel and high-level radioactive waste, based on the concept of the RMEI. This involves estimating the dose to a person assumed to be among those at greatest risk for 10,000 years after repository closure, given certain conservative exposure parameters and parameter value ranges. The Environmental Protection Agency selected a theoretical individual representative of a future population group or community, termed *rural-residential*, as the basis of an individual exposure scenario. This rural-residential RMEI would be exposed through the same general pathways as a subsistence farmer; however, the RMEI would not be a full-time farmer but rather would consume some locally grown food (self-grown or from local sources) as part of the exposure scenario. The Environmental Protection Agency also established a maximum 300-square-kilometer (74,000-acre)-controlled area, and established a RMEI location that equates to approximately 18 kilometers (11 miles) south of the repository (the predominant direction of groundwater flow), for demonstrating compliance with the long-term performance standards. The Environmental Protection Agency standard defines the postclosure accessible environment as being any point outside the controlled area.

For purposes of estimating potential environmental impacts in this EIS, DOE considered the impacts to the RMEI approximately 18 kilometers (11 miles) downgradient from the repository, as well as at other reasonable locations. In determining those locations, DOE considered locations where it would be reasonable from a technical and economic standpoint to locate a rural-residential individual. Although there exists a large number of locations at which analyses could be performed, DOE has determined that the most reasonable analyses to perform are for a rural-residential individual approximately 18, 30, and 60 kilometers (11, 19, and 37 miles) downgradient from the proposed repository, because these locations are based on realistic exposure conditions that would provide the basis for a meaningful comparison of potential human health impacts.

The Environmental Protection Agency, in reaching its conclusion on the location of the southernmost extent of the controlled area, considered current and projected uses of the land in the vicinity of the area formerly known as Lathrop Wells [now known as Amargosa Valley, approximately 20 kilometers (12 miles) downgradient from the repository]. The Agency noted there are currently eight residents and fewer than 10 businesses near this location whose source of water is the aquifer that flows beneath Yucca Mountain. This is the location where private property is nearest the proposed repository, and where some soils are suitable for agricultural purposes [the nearest farm is somewhat farther south, about 23 kilometers (14 miles) downgradient from the repository]. The Agency used near-term projections of land development between the current population at Amargosa Valley north to the Nevada Test Site. Near-term plans for the area between Amargosa Valley and the Test Site boundary include a science museum and industrial activities. Therefore, the boundary of the Test Site was used as the southernmost extent of the controlled area in 40 CFR 197.12. For this EIS, DOE adopted the southernmost extent of the controlled area as the RMEI location. This location is about 18 kilometers (11 miles) downgradient from the proposed repository.

DOE also has identified other reasonable locations for a hypothetical rural-residential individual approximately 30 and 60 kilometers (19 and 37 miles) downgradient from the repository. The closest population center is 30 kilometers (19 miles) downgradient in Amargosa Valley. At this location, the depth to groundwater suitable for human consumption and other uses (for example, agricultural) ranges from about 9 to 40 meters (30 to 130 feet) deep (less than that at the location formerly known as Lathrop Wells), and wells supply water to individual households. Franklin Lake Playa is about 60 kilometers (37 miles) downgradient from the proposed repository and is the location where the aquifer could emerge as surface water.

In conclusion, these three locations where a rural-residential individual could be reasonably located [about 18, 30, and 60 kilometers (11, 19, and 37 miles) downgradient] represent realistic locations where water for human consumption and other uses can occur using commonly available techniques without undue costs to withdraw and distribute water. These locations also reflect current populations and lifestyles in areas where dissolved radionuclides in the groundwater could affect future populations.

In the Draft EIS, DOE analyzed a Maximally Exposed Individual at a location 5 kilometers (3 miles) from the repository. The Maximally Exposed Individual was defined as a hypothetical person exposed to radiation in such a way—by a combination of factors including location, lifestyle, dietary habits, and so on—that the individual would be the most highly exposed member of the public. The Maximally Exposed Individual in the Draft EIS was a hypothetical member of a group of adults that would live in the Amargosa Valley with a characteristic range of lifestyle, food consumption, and groundwater usage patterns. This individual would grow half of the foods that the individual would consume on the property, irrigate crops and water livestock using groundwater, and use groundwater as a drinking water source and to bathe and wash clothes. The lifestyle and related exposure characteristics of the Maximally Exposed Individual are similar to those of the Environmental Protection Agency's rural-residential RMEI.

DOE noted in the Draft EIS that there are no permanent residents at a location 5 kilometers (3 miles) downgradient from the repository. The water table lies more than 360 meters (1,200 feet) deep in hard, volcanic rock. Although it might be possible, DOE would not expect permanent residents at that location in the future because of a lack of economically accessible groundwater. Human habitation has occurred in the vicinity of the repository where only the groundwater is easily accessible. Furthermore, the lands in this area are under the control of the Federal Government and within the controlled area defined in 40 CFR Part 197 – and thus are not part of the postclosure accessible environment.

In spite of these factors, DOE analyzed a Maximally Exposed Individual at a location 5 kilometers (3 miles) downgradient of the repository in the Draft EIS. At the time of the Draft EIS, Environmental Protection Agency had not published its draft or final radiation protection standards for Yucca Mountain, but DOE believed that a 5-kilometer compliance location could be established by the Environmental Protection Agency, given a similar compliance location in its generally applicable standards for the disposal of spent nuclear fuel, high-level radioactive waste and transuranic waste (40 CFR 191).

However, the Environmental Protection Agency has since published its final Yucca Mountain-specific public health and environmental radiation protection standards, and has concluded:

> "…it improbable that the rural-residential RMEI [reasonably maximally exposed individual] would occupy locations significantly north of U.S. Route 95 [location formerly known as Lathrop Wells], because the rough terrain and increasing depth to ground water nearer Yucca Mountain would likely discourage settlement by individuals because access to water is more difficult than it would be a few kilometers farther south."

The Environmental Protection Agency considered whether or not the inherent nature of the soils and the topography were conducive to or would constrain further development of the area near Yucca Mountain. The Agency concluded that:

> "…agricultural activity would be limited around Yucca Mountain as a result of adverse conditions, such as steep slopes, rocky terrain, and shallow soils…"

The Environmental Protection Agency also considered the potential dose to a RMEI at locations closer than approximately 18 kilometers (11 miles), and concluded that a rural-residential individual would receive a lower dose than those at 18 kilometers. The Agency stated that:

> "If individuals lived near the repository, they would be unlikely to withdraw water from the significantly greater depth for other than domestic use, and in the much larger quantities needed for gardening or farming activities because of the significant cost of finding and withdrawing the ground water. It is possible, therefore, for an individual located closer to the repository to incur exposures from contaminated drinking water, but not from ingestion of contaminated food. Based upon our analyses…we believe that use of contaminated ground water…would be the most likely pathway for most of the dose from the most soluble, more mobile radionuclides…The percentage of the dose that results from irrigation would depend upon assumptions about the fraction of all food consumed by the RMEI from gardening or other crops grown using contaminated water, which should reflect the

> lifestyle of current residents of the Town of Amargosa Valley. Therefore, the exposure of an RMEI located approximately 18 km south of the repository…actually would be more conservative than an RMEI located much closer to the repository…"

The Agency also addressed the economic feasibility of well drilling and pumping costs and concluded that:

> "…the capital costs of private wells for domestic use become prohibitive at depths between 300 and 600 feet. For communal domestic use and irrigation use, the capital costs do not become prohibitive even at depths of 1,200 feet…However, because of the very large volumes of water needed for irrigating field crops, particularly in the climate of Amargosa Valley, pumping costs are very significant for such agricultural applications. Combining the pumping cost estimates…with the capital cost estimates…the marginal value of water for irrigation is exceeded at depths to water greater than 300 feet. In fact, since these estimates do not consider the distribution cost for the irrigation system or any maintenance costs…it is not surprising to see that commercial agricultural activities in Amargosa Valley have been restricted thus far to areas where the depth to water is generally less than about 200 feet."

Based on the above considerations, DOE did not reevaluate the impacts at 5 kilometers (3 miles). This EIS contains evaluations of impacts at the RMEI location, at 30 kilometers (19 miles) downgradient from the repository (population center), and at the groundwater surface discharge point 60 kilometers (37 miles) downgradient from the repository.

I.4.5.2 Scaling Approach

This section summarizes the approach detailed in DIRS 157520-Williams (2001, Enclosure 3).

As the plume traveled over a given distance in the saturated zone, the concentration of radionuclides in the plume could be attenuated by several effects: dispersion, decay, filtration of solids by the aquifer medium, irreversible sorption of radionuclides by the aquifer medium, and other minor phenomena. The dispersion effects would be due to the combination of molecular diffusion and hydrodynamic mixing, that would tend to cause the contaminants to spread out along and transverse to the path of flow. The dispersion effect would reduce the peak concentration of the plume and increase the volume of the plume. The decay effect would be due to the later arrival of the plume centerline at a farther distance, allowing time for nuclear decay. The travel time would depend on the flow rate of the water and the retardation of contaminants that were sorbed reversibly by the aquifer solid media. The overall reduction by decay would be governed by the radionuclide travel time and the rate of decay of a particular radionuclide. The effects of colloid filtration, irreversible sorption, and other minor phenomena are expected to be small and are normally neglected. The principal radionuclides that would contribute to dose and most significantly affect groundwater quality have very long half-lives (and therefore very slow rates of decay), so the reduction of concentration by decay would be fairly small. The major contributor to the reduction of concentration in the contaminant plume, then, would be the dispersion effect. Therefore, the scaling approach was developed from only the dispersion effect. This produced a conservative result because the decay effect will cause some small additional reduction in concentration.

All of the major attenuating effects listed above were applied in the TSPA model for the calculation of the dose and water quality at the compliance point. However, because most of the path from the proposed repository to the compliance point is in the volcanic aquifer, there is only a small amount of dispersion. The volcanic aquifer is comprised mostly of fractured rock, so flow occurs in small isolated channels and mixing is minimal. This is why the plume is still small at the compliance point and full capture is a reasonable assumption. In the alluvial aquifer that extends from the RMEI location down to the discharge point, the aquifer medium is a finely divided, granular material where flow is slow and considerably more mixing can occur.

An analytical solution to the three-dimensional advection-dispersion problem was used to estimate dispersion effects from the RMEI location to the discharge point (DIRS 157520-Williams 2001, Enclosure 3, all). In these calculations, the groundwater flow velocity in the alluvium was assumed to be horizontal with a constant value of 18 meters (59 feet) per year, corresponding to a specific discharge rate of 2.7 meters (9 feet) per year and an effective porosity of 15 percent throughout the flow domain. These values were derived from the saturated zone site-scale model documented in DIRS 155950-BSC (2001, Section 12). Calculations were done under steady-state conditions, that is, for a source that has been discharging for a long time. The source was assumed to have constant concentration, be within a rectangular shape in the vertical plane, and centered at the repository location. Two source sizes were considered: a small source, 10 meters by 10 meters (33 feet by 33 feet), corresponding to an early failure scenario (localized failing waste package), and a large source, 3,000 meters (9,840 feet) horizontal by 10 meters (32.8 feet) vertical, corresponding to a long-term scenario in which all waste packages would fail.

The calculations were carried out for a range of dispersivities and for two assumed mass captures: 90 percent and 99 percent. The mass capture is a function of the amount of influence a well or field of wells would have in pulling mass from the plume. The results discussed here are restricted to the more conservative 99-percent capture assumption. Two important parameters were considered: the cross-section (perpendicular to flow) of the plume and the relative peak concentration at the center of the plume. As the plume traveled in the groundwater it would spread, so the cross-section would increase (thus reducing the average concentration) and the peak concentration would decrease. A reasonable approximation of distance effect can then be found by using either of these values. The two values will produce a slightly different result. Scaling factors using both approaches are discussed in the next section.

I.4.5.3 Scaling Factors for Dose or Water Quality Concentrations at Longer Distances

Table I-12 lists the resulting scaling factors from the dispersion studies (DIRS 157520-Williams 2001, Enclosure 3, Table 2a). The values are for the assumption of 99-percent capture, the larger realistic dispersion factor set, and two source sizes. The large source size would be applied for nominal scenario peak dose and the small source for localized sources such as the early failures (prior to 10,000 years) due to package defects or igneous intrusion releases, or for doses from the human intrusion scenario. Two sets of scaling factors are listed for each source size: one based on peak concentration and one based on plume cross-section. To obtain a value of dose or groundwater quality concentration at 30 or 60 kilometers (18 or 37 miles), multiply the 18-kilometer (11-mile) value by the appropriate scaling factor. The scaled results reported in Chapter 5, Section 5.4.1, use the plume cross-section factors. This is considered the best choice because the effect of water usage by the communities would be to cause significant mixing, and the more characteristic parameter would be the plume average concentration.

I.5 Waterborne Radioactive Material Impacts

The simulations in support of this analysis estimated the annual individual dose for the Proposed Action, Module 1, and Module 2 inventories. For the purposes of this EIS, DOE determined that the southern boundary of the controlled area would be at the southernmost point from the repository specified in 40 CFR Part 197 (36 degrees, 40 minutes, 13.6661 seconds north latitude). The RMEI location was then defined to be the point where the predominate groundwater flow crosses the boundary. Groundwater modeling indicated this point to be approximately 18 kilometers (11 miles) downgradient from the potential repository. This EIS refers to this location as the “RMEI location.” It corresponds to where the RMEI, a resident in an average farming community, would consume and use groundwater withdrawn from wells. In accordance with 40 CFR 197.35, the annual individual dose was calculated for the period of geologic stability (1 million years). These calculations include simulations for both the 10,000- and 1 million-year performance periods specified in 40 CFR 197.20 and 197.35.

Table I-12. Groundwater impact distance scale factors[a,b] for 99-percent captured mass, longitudinal dispersivity 100 meters,[c] horizontal dispersivity 10 meters, and vertical dispersivity 0.1 meters.

	Scale factors	
Source	18 kilometers[d] to 30 kilometers	18 kilometers to 60 kilometers
Large source: 3,000 × 10 meters		
Based on plume cross-section	0.68	0.39
Based on relative peak concentration	0.74	0.46
Small source: 10 × 10 meters		
Based on plume cross-section	0.70	0.48
Based on relative peak concentration	0.60	0.30

a. Derived from DIRS 157520-Williams (2001, Enclosure 3, Table 2a).
b. To convert an 18-kilometer result to a 30- or 60-kilometer result, multiply the dose or the concentration by the appropriate value in the table.
c. To convert meters to feet, multiply by 3.281.
d. To convert kilometers to miles, multiply by 0.6214.

The calculations in this EIS also show the peak dose for all scenarios. The location is also where a representative volume of groundwater would be withdrawn and where there would be a reasonable expectation that radiation would not exceed the limits of 40 CFR 197.30, Table 1. This EIS also reports groundwater protection values at that location.

The data from the multiple realizations can be summarized by showing time versus annual individual dose (dose histories) for the 5th-percentile, median, mean, and 95th-percentile of the output. In the manner described for TSPA–Site Recommendation (DIRS 153246-CRWMS M&O 2000, Section 2.2.4.6, pp. 2-39 to 2-40), these statistical measures were calculated for all 300 realizations of the probabilistic simulations at each time step of the annual individual dose histories. The plot of the mean represents the average of all 300 data points at each time step. For each point on the plot of the median dose, 50 percent of the data have a value greater than the plotted point and 50 percent have a value less than the plotted point. Similarly, for the 5th- and 95th-percentiles, the plotted data points are such that 95 percent of data are greater than the plotted point and 5 percent of the data points are greater than the plotted points, respectively, for each time step. The statistical measures were superimposed on plots that show all 300 realizations (often referred to as “horsetail plots”).

I.5.1 WASTE PACKAGE FAILURE

Figure I-8 shows the waste package failure curves for the Proposed Action for the 1-million-year performance period for the higher-temperature operating mode. The figure indicates that the first waste package failures would occur within 10,000 years of repository closure. These early waste package failures result from the assumption of improper heat treatment (see Section I.2.4 and Table I-3). The 300 realizations are shown in Figure I-8. During the first 10,000 years there are some realizations showing a failure fraction of 0.00025, which when multiplied times the total waste packages (11,770) gives a maximum of 3 early waste package failures. There are some realizations that show zero failures, but this is not readily evident from the figure. Waste package failure would be the first step in releasing radionuclides for groundwater flow and transport.

Figure I-9 shows cladding perforated during the postclosure period. The calculations included the averaged impact of seismic events. The cladding failure results shown in Figure I-9 are essentially the same as those developed in the *FY01 Supplemental Science and Performance Analyses* (DIRS 154659-BSC 2001, pp. 9-19 to 9-23).

I.5.2 ANNUAL INDIVIDUAL DOSE FOR 10,000 YEARS AFTER CLOSURE

This section presents graphic representations of annual individual doses for the inventories described in Section I.3 and the scenarios described in Section I.4. The performance period for the calculations in this EIS was generally 1 million years after repository closure except in the case of the igneous activity scenarios. The annual dose histories for the igneous activity scenarios were only calculated for 100,000 years after closure because the releases from the nominal scenario dominate after that time. In addition to the graphic presentations, Table I-13 lists the values of the peak mean annual individual dose for all scenarios that would occur in the 10,000-, 100,000-, and 1-million-year postclosure performance periods, in accordance with 40 CFR 197.20, 197.25, and 197.35. Table I-14 lists the same information for the peak 95th-percentile annual individual dose.

Table I-13. Peak mean annual individual doses (millirem) for analyzed inventories, scenarios, and temperature operating modes.[a,b]

Modeled inventory, scenario, and operating mode	10,000 years		100,000 years		1 million years	
	Value	Year	Value	Year	Value	Year
Proposed Action, nominal, higher-temperature	0.000017	4,875	0.12	99,500	152.5	476,000
Proposed Action, nominal lower-temperature	0.000011	3,437.5	0.085	99,500	122.2	476,000
Inventory Module 1, nominal, higher-temperature	0.000027	4,937.5	0.16	100,000	237.9	476,000
Inventory Module 2, nominal, higher-temperature[c]	0.00066	2,875	0.00066	2,875	0.33	208,000
Proposed Action, igneous activity, higher-temperature	0.10	312.5	0.10	312.5	NC[d]	NC
Proposed Action, igneous activity, lower-temperature	0.10	312.5	0.10	312.5	NC	NC
Proposed Action, igneous activity (intrusive only), higher-temperature	0.00043	10,000	0.021	48,000	NC	NC
Proposed Action, igneous activity (intrusive only), lower-temperature	0.00050	10,000	0.028	48,000	NC	NC
Proposed Action, igneous activity (eruptive only), higher-temperature	0.10	312.5	0.10	312.5	NC	NC
Proposed Action, igneous activity (eruptive only), lower-temperature	0.10	312.5	0.10	312.5	NC	NC
Proposed Action, human intrusion at 30,000 years, higher-temperature	NA[e]	NA	0.0017	30,562.5	0.0023	108,000

a. Adapted from DIRS 157307-BSC (2001, Enclosure 1).
b. These data are based on the same probabilistic annual water usage model used in the TSPA–Site Recommendation (not 3,000 acre-feet per year).
c. Module 2 runs only included the incremental effect of the additional inventory from Greater-Than-Class-C and Special-Performance-Assessment-Required waste.
d. NC = not calculated.
e. NA = not applicable.

I.5.3 ANNUAL INDIVIDUAL DOSE FOR 1,000,000 YEARS AFTER CLOSURE

Results for annual individual dose calculations for 1 million years following closure are discussed for the Proposed Action (Section I.5.3.1), Inventory Module 1 (Section I.5.3.2) and Inventory Module 2 (Section I.5.3.3).

Table I-14. Peak 95th-percentile annual individual doses (millirem) for analyzed inventories, scenarios, and temperature operating modes.[a,b]

Modeled inventory, scenario, and operating mode	10,000 years		100,000 years		1,000,000 years	
	Value	Year	Value	Year	Value	Year
Proposed Action, nominal, higher-temperature	0.00012	4,937.5	0.040	99,500	618.0	408,000
Proposed Action, nominal, lower-temperature	0.000086	5,000	0.034	100,000	513.2	408,000
Inventory Module 1, nominal, higher-temperature	0.00018	4,125	0.079	100,000	976.7	476,000
Inventory Module 2, nominal, higher-temperature[c]	0[d]	NA[e]	0.0013	100,000	1.5	208,000
Proposed Action, igneous activity, higher-temperature	0.41	312.5	0.41	312.5	NC[f]	NC
Proposed Action, igneous activity, lower-temperature	0.41	312.5	0.41	312.5	NC	NC
Proposed Action, igneous activity (intrusive only), higher-temperature	0.00029	9,750	0.052	100,000	NC	NC
Proposed Action, igneous activity (intrusive only), lower-temperature	0.00031	9,875	0.033	48,000	NC	NC
Proposed Action, igneous activity (eruptive only), higher-temperature	0.41	312.5	0.41	312.5	NC	NC
Proposed Action, igneous activity (eruptive only), lower-temperature	0.41	312.5	0.41	312.5	NC	NC
Proposed Action, human intrusion at 30,000 years, higher-temperature	NA	NA	0.0045	38,500	0.0045	38,400

a. Adapted from DIRS 157307-BSC 2001, Enclosure 1.
b. These data are based on the same probabilistic annual water usage model used in the TSPA–Site Recommendation (not 3,000 acre-feet per year).
c. Module 2 runs only included the incremental effect of the additional inventory from Greater-Than-Class-C and Special-Performance-Assessment-Required waste.
d. The mean dose is driven by 3 realizations that experience early failures; no other realizations result in a dose before 10,000 years so that the 95th-percentile value is zero.
e. NA = not applicable.
f. NC = not calculated.

I.5.3.1 Annual Individual Dose for the Proposed Action Inventory, Higher- and Lower-Temperature Repository Operating Modes

Figure I-10 shows the mean annual individual dose results of the 300 probabilistic simulations for the higher-temperature repository operating mode (approximately 56 MTHM per acre) for the Proposed Action inventory at the RMEI location for 1 million years after repository closure. Figure I-11 shows the relative contribution of selected radionuclides that contribute most to the total mean annual dose due to all radionuclides. Figure I-12 shows the results of the 300 probabilistic simulations of the Proposed Action inventory, higher-temperature operating mode, at the RMEI location for 1 million years after repository closure. This figure shows the results for each realization and the 5th-percentile, mean, median, and 95th-percentile of these simulations.

Figure I-10 also shows representations of the mean annual individual dose results of the 300 probabilistic simulations for the lower-temperature operating mode (approximately 45 MTHM per acre) for the Proposed Action inventory at the RMEI location for 1 million years after repository closure. Because Figure I-10 shows little difference between the annual individual dose histories calculated for the higher-temperature and the lower-temperature operating modes, the remaining scenarios, other than the igneous activity scenario, were simulated only for the higher-temperature operating mode. Figure I-13 shows the results of the 300 probabilistic simulations of the Proposed Action inventory, lower-temperature operating mode, at the RMEI location for 1 million years after repository closure. This figure shows the results for each realization and the 5th-percentile, mean, median, and 95th-percentile of these simulations.

I.5.3.2 Annual Individual Dose for Inventory Module 1, Higher-Temperature Repository Operating Mode

Figure I-14 displays the annual dose histories for the 300 probabilistic simulations of the expanded-inventory Module 1, higher-temperature operating mode at the RMEI location for 1 million years after repository closure. This figure shows the results for each realization and the 5th-percentile, mean, median, and 95th-percentile of these simulations.

I.5.3.3 Annual Individual Dose for Inventory Module 2, Higher-Temperature Repository Operating Mode

A GoldSim simulation was performed for a case that included only the Greater-Than-Class-C and Special-Performance-Assessment-Required components of the Module 2 inventory. The case did not include the other components of the Module 2 inventory (that is, the Module 1 inventory). The GoldSim simulation for only the Module 2 Greater-Than-Class-C and Special-Performance-Assessment-Required inventory, higher-temperature operating mode, was performed as a separate probabilistic case at the RMEI location. Figure I-15 shows the results of this simulation as the mean annual individual dose due to the radioactive components of this material. The effects of nonradioactive components of this waste are not included in the analysis.

Figure I-16 is a comparison plot of the mean annual dose versus time for the Proposed Action, Module 1, and the Greater-Than-Class-C and Special-Performance-Assessment-Required waste portion of the Module 2 inventories at the higher-temperature operating mode at the RMEI location. These results show that during the first 10,000 years, the mean annual individual dose due to the Greater-Than-Class-C and Special-Performance-Assessment-Required components of the Module 2 inventory would be greater than that calculated for the Proposed Action and Module 1 inventories, but still essentially zero. After 10,000 years, the dose due to the Greater-Than-Class-C and Special-Performance-Assessment-Required components of the Module 2 inventory would be about two orders of magnitude less than that calculated for the Proposed Action and Module 1 inventories. These results indicate that the addition of the Greater-Than-Class-C and Special-Performance-Assessment-Required waste to the Module 1 inventory would not materially increase the mean annual individual dose. Based on this comparison, separate probabilistic simulations were not run for the entire Inventory Module 2.

I.5.3.4 Annual Individual Dose for Igneous Activity Scenario, Higher- and Lower-Temperature Repository Operating Modes

The performance of a Yucca Mountain repository was evaluated for a combined igneous activity scenario that included both an igneous event and a volcanic eruption. The combined scenario was simulated for the higher- and lower-temperature repository operating modes for the Proposed Action inventory. Annual dose histories were not calculated for the igneous activity scenario for Modules 1 and 2.

Figure I-17 shows representations of the probability-weighted annual individual dose histories for 500 of the 5,000 probabilistic simulations for the igneous activity scenario, higher-temperature repository operating mode (approximately 56 MTHM per acre) for the Proposed Action inventory at the RMEI location for 100,000 years after repository closure. Figure I-17 also shows the 5th-percentile, mean, median, and 95th-percentile of all 5,000 igneous activity simulations. The results shown in the figure represent the combined effect of both the igneous-intrusion and eruptive events.

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Figure I-18 shows the mean annual individual dose versus time for the igneous activity scenario for the Proposed Action inventory for the higher-temperature operating mode at the RMEI location. The figure also shows the mean results for both the eruptive and intrusive events. Figure I-19 shows the mean annual individual dose for the igneous activity scenarios, representing the sum of the igneous and eruptive events, Proposed Action inventory for the higher- and lower-temperature operating modes at the RMEI location.

Figure I-20 shows representations of the probability-weighted annual individual dose histories for 500 of the 5,000 probabilistic simulations for the igneous activity scenario, lower-temperature repository operating mode (approximately 45 MTHM per acre) for the Proposed Action inventory at the RMEI location for 100,000 years after repository closure. Figure I-20 also shows the 5th-percentile, mean, median, and 95th-percentile of all 5,000 igneous activity simulations. The results presented in this figure represent the combined effect of both the igneous intrusion and eruptive events.

Figure I-21 shows the mean individual annual dose versus time for the igneous activity scenario for the Proposed Action inventory for the lower-temperature repository operating mode at the RMEI location. The figure also displays the mean results for both the eruptive and intrusive events.

I.5.3.5 Annual Individual Dose for the Human Intrusion Scenario

Figure I-22 displays representations of the annual individual dose results of the 300 probabilistic simulations for the human intrusion scenario, 30,000 years after repository closure, Proposed Action inventory for the higher-temperature operating mode at the RMEI location. Figure I-22 displays the results for each simulation and the 5th-percentile, median, mean, and 95th-percentile of these simulations.

I.5.4 COMPARISON TO GROUNDWATER PROTECTION STANDARDS

An analysis for groundwater protection was conducted in accordance with the Environmental Protection Agency Final Rule 40 CFR 197.30 and 197.31). The rule is based on meeting three groundwater radionuclide-concentration levels. The first is the maximum annual concentration of radium-226 and -228 in a representative volume of 3.7 million cubic meters (3,000 acre-feet) of groundwater in a release from the proposed repository. The second groundwater concentration is for the gross alpha activity (excluding radon and uranium) in the representative volume of groundwater. Both calculations apply to releases from both natural sources and releases from the repository at the same location as the RMEI. The third groundwater-protection calculation is the dose to the whole body or any organ of a human for beta- and photon-emitting radionuclides released from the repository. The human would consume 2.0 liters (0.53 gallon) per day from the representative volume of groundwater. This groundwater would be withdrawn annually from an aquifer containing less than 10,000 milligrams per liter (1.34 ounces per gallon) of total dissolved solids, and centered on the highest concentration in the plume of contamination at the same location as the RMEI. The results of the calculations for this EIS produced data consistent with the Environmental Protection Agency Final Rule and are presented graphically and in tabular form.

Figure I-23 shows the mean activity concentrations of gross alpha activity and total radium (radium-226 plus radium-228) in the representative volume of groundwater for the Proposed Action inventory, higher-temperature repository operating mode. The concentrations are calculated for a representative volume of water of 3.7 million cubic meters (exactly 3,000 acre-feet per year) at the same location as the RMEI at the accessible environment as described in 40 CFR 197.30. Naturally occurring background radionuclide concentrations were not included because the calculated values are negligible compared to background concentrations up to 100,000 years after closure. Figure I-24 shows the same information for the lower-temperature operating mode.

Figure I-25 shows the mean dose to the whole body or any organ for technetium-99, carbon-14, and iodine-129, the prominent beta and photon-emitting radionuclides (DIRS 154659-BSC 2001, Volume 2, Section 4.1.4, pp. 4 to 11) for the Proposed Action inventory, higher-temperature repository operating mode, for the 1-million-year performance period. Figure I-26 shows the same information for the lower-temperature operating mode.

The data developed for the groundwater protection standard are summarized in Table I-15, which lists the peak mean gross alpha activity by scenario for various performance periods; Table I-16, which lists peak total radium concentration by scenario for various performance periods; and Table I-17, which lists the combined whole-body or organ doses in 10,000 years for the total of all beta- and photon-emitting radionuclides. The mean whole-body or organ dose was calculated by diluting the model-predicted annual activity releases of iodine-129, carbon-14, and technetium-99 [the prominent beta and photon-emitting radionuclides (DIRS 154659-BSC 2001, Volume 2, Section 4.1.4, pp. 4 to 11)] in the representative volume of groundwater (3,000 acre-feet per year). The resulting concentrations for each time step were converted to equivalent doses by scaling the appropriate dose conversion factor (4 millirem per 2,000 picocurie per liter for carbon-14; 4 millirem per 1 picocurie per liter for iodine-129; and 4 millirem per 900 picocurie for technetium 99). Calculating the sum of these three radionuclide doses for each time step produced a time history of whole-body or organ dose; the peak within 10,000 years was identified and is reported in Table I-17. This process is repeated for 95th-percentile whole-body or organ dose using model-predicted 95th-percentile annual activity releases of the prominent beta and photon-emitting radionuclides.

I.6 Waterborne Chemically Toxic Material Impacts

Several materials that are chemically toxic would be used in the construction of the repository. A screening analysis was used to determine which, if any, of these materials would have the potential to be transported to the accessible environment in quantities sufficient to be toxic to humans.

Chemicals included in the substance list for the Environmental Protection Agency's Integrated Risk Information System (DIRS 103705-EPA 1997, all; DIRS 148219, 148221, 148224, 148227, 148228, 148229, and 148233-EPA 1999, all) were evaluated to determine a concentration that would be found in drinking water in a well downgradient from the repository. The chemicals on the Integrated Risk Information System substance list that would be in the repository are barium, boron, cadmium, chromium, copper, lead, manganese, mercury, molybdenum, nickel, selenium, uranium, vanadium, and zinc.

I.6.1 SCREENING ANALYSIS

The results of the analysis of long-term performance for radionuclides detailed in Section I.5 show that, at most, three waste packages would be breached prior to 10,000 years (due to improper heat treatment) under the Proposed Action. The period of consideration for chemical toxic materials impacts was 10,000 years. Therefore, only toxic materials outside the waste package were judged to be of concern in this analysis. These are chromium, copper, manganese, molybdenum, nickel, and vanadium.

I.6.1.1 Maximum Source Concentrations of Chemically Toxic Materials in the Repository

Maximum source concentrations were calculated to provide the maximum possible concentration of that element in water entering the unsaturated zone. For materials that were not principally part of the Alloy-22 (copper and manganese), the maximum source concentration was taken to be the solubility of the material in repository water. The solubilities were obtained by modeling with the EQ3 computer code (DIRS 100836-Wolery 1992, all). The simulations were started with water from well J-13 near the Yucca Mountain site (DIRS 100814-Harrar et al. 1990, all). EQ3 calculates chemical equilibrium of a system so that, by making successive runs with gradually increasing aqueous concentrations of an element,

Table I-15. Peak mean gross alpha activity for analyzed inventories, scenarios, and temperature operating modes.[a,b]

Modeled inventory, scenario[c], and operating mode	10,000 years		100,000 years		1 million years	
	Without background	With background[d]	Without background	With background	Without background	With background
Proposed Action, nominal, higher-temperature	1.8×10^{-8}	0.40	0.017	0.42	17.7	18.1
Proposed Action, nominal, lower-temperature	3.3×10^{-8}	0.40	0.010	0.41	14.2	14.6
Inventory Module 1, nominal, higher-temperature	3.3×10^{-8}	0.40	0.023	0.42	27.7	28.1
Inventory Module 2, nominal, higher-temperature	2.2×10^{-10}	0.40	0.000042	0.40	0.039	0.44
Proposed Action, human intrusion event at 30,000 years, higher-temperature	NA[e]	NA	0.00018	0.40	0.00031	0.40

a. Adapted from DIRS 157307-BSC (2001, Enclosure 1).
b. These results are based on an annual water usage equal to 3.7 million cubic meters (exactly 3000 acre-feet) per year.
c. Mean gross alpha activity is not available for igneous activity scenarios
d. Background alpha activity concentration is 0.4 picocurie per liter.
e. NA = not applicable.

Table I-16. Peak mean total radium concentration (picocuries per liter) for analyzed inventories, scenarios, and temperature operating modes.[a,b]

Modeled inventory, scenario[c], and operating mode	10,000 years		100,000 years		1 million years	
	Without background	With background[d]	Without background	With background	Without background	With background
Proposed Action, nominal, higher-temperature	1.1×10^{-11}	1.0	2.4×10^{-5}	1.0	0.33	1.4
Proposed Action, nominal, lower-temperature	2.4×10^{-12}	1.0	2.7×10^{-5}	1.0	0.27	1.3
Inventory Module 1, nominal, higher-temperature	3.3×10^{-10}	1.0	4.0×10^{-5}	1.0	0.67	1.7
Inventory Module 2, nominal, higher-temperature	6.7×10^{-13}	1.0	6.8×10^{-9}	1.0	0.0016	1.0
Proposed Action, human intrusion event at 30,000 years, higher-temperature	NA[e]	NA	2.4×10^{-7}	1.0	3.8×10^{-7}	1.0

a. Adapted from DIRS 157307-BSC (2001, Enclosure 1).
b. These results are based on an annual water usage equal to 3.7 million cubic meters (exactly 3000 acre-feet) per year.
c. Total radium concentration is not available for igneous activity scenarios
d. Background radium activity concentration is 1.04 picocuries per liter.
e. NA = not applicable.

Table I-17. Peak mean annual whole body or organ dose (millirem)[a] for the sum of all beta- and photon-emitting radionuclides during 10,000 years after closure for analyzed inventories, scenarios, and temperature operating modes.[b]

Modeled inventory, scenario and operating mode	Total
Proposed Action, nominal, higher-temperature	2.3×10^{-5}
Proposed Action, nominal, lower-temperature	1.3×10^{-5}
Proposed Action, human intrusion event at 30,000 years, higher-temperature	NA[c]
Inventory Module 1, nominal, higher-temperature operating mode	2.8×10^{-5}

a. This represents a bounding limit (overestimate) of the maximum dose to any organ because different radionuclides would affect different organs preferentially.
b. These results are based on an annual water usage equal to 3.7 million cubic meters (exactly 3000 acre-feet) per year.
c. NA = not applicable.

eventually a result will show the saturation of a mineral in that element. That concentration at which the first mineral saturates is said to be the "solubility." The solubility of copper (from the electrical bus bars left in the tunnels) was obtained by increasing copper concentrations in successive runs of EQ3. At a concentration of 0.018 milligram per liter, copper began to precipitate as tenorite (CuO). This mineral was then in equilibrium with dissolved copper existing in approximately equal molar parts as $CuOH^+$, $Cu(CO_3)aq$, and Cu^{++}. A similar approach for manganese gave a solubility of 4.4×10^{-10} milligram per liter as pyrolusite (MnO_2) began to precipitate. In the cases of chromium, molybdenum, nickel, and vanadium, the source concentration has a potential to be very high because the corrosion of Alloy-22 could result in a very low pH solution (much different from the repository water). Thus, for purposes of screening, it was assumed that these materials had a potentially very high source concentration and should be subjected to further screening analysis (this is discussed in Section I.6.2).

I.6.1.2 Further Screening for Chemically Toxic Materials

Manganese was further analyzed using a comparison of intake to the Oral Reference Dose. The Oral Reference Dose is an indication of the limit for possible health effects from oral ingestion. Intake was based on a 2-liter (0.53-gallon) daily consumption rate of drinking water, at the maximum source concentrations (solubilities), by a 70-kilogram (154-pound) adult. Calculation takes no credit for any dilution from the source to the recipient. For manganese, the intake would be 2.2×10^{-12} milligram per kilogram per day. This is very small compared to the Oral Reference Dose of 0.14 milligram per kilogram per day listed for manganese in the Integrated Risk Information System (DIRS 148227-EPA 1997, all). Thus, it is concluded that manganese requires no further consideration.

No Oral Reference Dose is available for copper, but a similar evaluation can be made by comparing the maximum source concentration to a maximum concentration limit for the drinking water standard (40 CFR 141.2). For copper the maximum contaminant limit is 1.3 milligrams per liter. This is much higher than the source concentration of 0.018 milligram per liter, so it is concluded that copper requires no further consideration.

ORAL REFERENCE DOSE

The *Oral Reference Dose* is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis. This dose is expressed in units of milligrams per kilogram per day. In general, the oral reference dose is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime (DIRS 148219-EPA 1999, all).

The remaining hazardous elements of concern (chromium, molybdenum, nickel, and vanadium) are analyzed in the next section.

I.6.2 BOUNDING CONSEQUENCE ANALYSIS FOR CHEMICALLY TOXIC MATERIALS

Further evaluation is warranted because the first level of the screening analysis (Section I.6.1) indicated that the repository could release certain waterborne chemically toxic materials into groundwater in substantial quantities and that these could represent a potential human health impact. The following materials require further evaluation: chromium, molybdenum, nickel, and vanadium. A bounding calculation for concentrations in the biosphere is presented in this section for these elements that shows the impacts would be low enough to preclude any need for more detailed fate and transport analyses.

I.6.2.1 Assumptions

The following assumptions were applied to the bounding impact analysis for waterborne chemically toxic materials:

1. The general corrosion rate of Alloy-22 is equivalent for humid-air and aqueous corrosion conditions (this assumption is consistent with treatment of this substance in the TSPA–Site Recommendation).

2. The general corrosion rate of Alloy 316NG (stainless steel) is also equivalent for humid air and aqueous corrosion conditions.

3. Consistent with Assumptions 1 and 2 above, drip shields were not assumed to effectively delay onset of general corrosion of Alloy-22 in the outer barrier layer of waste packages or the emplacement pallets.

4. Consistent with Assumptions 1, 2, and 3 above, exposed Alloy-22 and stainless steel 316NG in the drip shield rail, waste packages, and emplacement pallets would all be subject to corrosion at the same time.

5. Consistent with Assumptions 1, 2, and 3 above, all waste packages would be subject to general corrosion at the same time, and would not experience variability in the time corrosion begins.

6. The median corrosion rates for Alloy-22 and stainless steel 316NG were used in the impact estimate calculations because the rates apply to all waste packages, drip shields, and emplacement pallets in the repository.

7. A migration pathway for mobilized waterborne chemically toxic materials through the engineered barrier system to the vadose zone was assumed to exist at all times general corrosion is in progress.

8. Time delays, mitigation effects by sorption in rocks, and other beneficial effects of transport in the geosphere were neglected for purposes of this bounding impact estimate; the mass of waterborne chemically toxic materials mobilized was assumed to be instantly available at the biosphere exposure locations.

9. The concentration in groundwater was estimated by diluting the released mass of waterborne chemically toxic materials in the representative volume defined by the Environmental Protection Agency [3.7 million cubic meters (exactly 3,000 acre-feet) of water per year] in 40 CFR Part 197.

10. Under the chemical environment of the waste package, all chromium, molybdenum, nickel, and vanadium were assumed to be in their most soluble and toxic state. This is a highly conservative assumption but is consistent with other modeling of the waste package chemical environment.

11. Mobilization of chromium, molybdenum, nickel, and vanadium was assumed equivalent to the corrosion loss of stainless steel or Alloy-22 times the fraction of each element in the alloys.

12. Throughout the discussions in Section I.6.2 it is assumed that the form of mobilized chromium is the hexavalent form. The hexavalent form of chromium [Cr(VI)] is considered potentially hazardous, whereas the more common corrosion product, trivalent chromium [Cr(III)], is not. This is a conservative assumption because DOE believes that most of the mobilized Cr would be the trivalent form.

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I.6.2.2 Surface Area Exposed to General Corrosion

Corrosion of the materials bearing chromium and molybdenum would occur over all exposed surface areas. The total exposed surface area of Alloy-22 surfaces (drip shield rails, outer layer of waste packages, and portions of the emplacement pallets) and stainless-steel 316NG surfaces (portions of the emplacement pallets) are calculated in this section.

Tables I-18 and I-19 summarize the calculation of the total exposed surface areas for Alloy-22 contained in the waste packages and drip shields, respectively, under the Proposed Action.

Table I-18. Total exposed surface area of the Alloy-22 outer layer of all waste packages under the Proposed Action inventory.

Waste package type[a]	Number[b]	Outer diameter[a] (millimeters)[b]	Length[a] (millimeters)[b]	Surface area[c] (square millimeters)[d]	Total surface area (square meters)[e]
21 PWR absorber plate	4,299	1,664	5,165	31,349,978	134,774
21 PWR control rods	95	1,664	5,165	31,349,978	2,978
12 PWR absorber plate	163	1,330	5,651	26,390,258	4,302
44 BWR absorber plate	2,831	1,674	5,165	31,564,675	89,360
24 BWR thick absorber plate	84	1,318	5,105	23,866,529	2,005
5 DHLW/DOE SNF	1,592	2,110	3,590	30,790,593	49,019
5 DHLW/DOE SNF–long	1,751	2,110	5,217	41,575,586	72,799
Navy SNF	200	1,949	5,430	39,214,523	7,843
Navy SNF–long	100	1,949	6,065	43,102,606	4,310
2 MCO/2 HLW	186	1,815	5,217	34,921,842	6,495
Totals	***11,301***				***373,884***

a. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
b. To convert millimeters to inches, multiply by 0.0394.
c. Surface area calculated as area of a right circular cylinder.
d. To convert square millimeters to square inches, multiply by 0.00155.
e. To convert square meters to square feet, multiply by 10.764.

Table I-19. Total exposed surface area of the Alloy-22 rails for all drip shields under the Proposed Action inventory.

Component	Number of pieces	Average waste package emplacement length[a] (millimeters)[b]	Width[c] (millimeters)[d]	Thickness[c] (millimeters)	Total surface area per average waste package[e] (square millimeters[f])	Number of waste packages[c]	Total surface area for repository (square meters[g])
Rail	2	5,076	115	10	1,370,520	11,301	15,488

a. Emplacement length estimate from DIRS 155393-CRWMS M&O (2000, Attachment V, p. V-2).
b. To convert meters to feet, multiply by 3.2808.
c. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
d. To convert millimeters to inches, multiply by 0.0394.
e. Surface area calculated as sum of areas of wetted surfaces (two rectangles) of angles running along the bottom of both sides of the drip shield.
f. To convert square millimeters to square inches, multiply by 0.00155.
g. To convert square meters to square feet, multiply by 10.764.

Tables I-20 and I-21 summarize the calculation of the total exposed surface areas for Alloy-22 contained in the waste packages and drip shields, respectively, for the Module 1 inventory.

Tables I-22 and I-23 summarize the calculation of the total exposed surface areas for Alloy-22 contained in the waste packages and drip shields respectively, for the Module 2 inventory.

Table I-24 summarizes the calculation of total exposed surface area for the Alloy-22 components of the emplacement pallets for the Proposed Action, Module 1, and Module 2 inventories.

Table I-20. Total exposed surface area of the Alloy-22 outer layer of all waste packages for the Module 1 inventory.

Waste package type	Number[a]	Outer diameter[a] (millimeters)[b]	Length[a] (millimeters)	Surface area[c] (square millimeters)[d]	Total surface area (square meters)[e]
21 PWR absorber plate	6,733	1,664	5,165	31,349,978	211,079
21 PWR control rods	114	1,664	5,165	31,349,978	3,574
12 PWR absorber plate	390	1,330	5,651	26,390,258	10,292
44 BWR absorber plate	4,408	1,674	5,165	31,564,675	139,137
24 BWR thick absorber plate	109	1,318	5,105	23,866,529	2,601
5 DHLW/DOE SNF	1,557	2,110	3,590	30,790,593	47,941
5 DHLW/DOE SNF–long	2,821	2,110	5,217	41,575,586	117,285
Navy SNF	200	1,949	5,430	39,214,523	7,843
Navy SNF–long	100	1,949	6,065	43,102,606	4,310
2 MCO/2 HLW	199	1,815	5,217	34,921,842	6,949
Totals	***16,631***				***551,012***

a. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
b. To convert millimeters to inches, multiply by 0.0394.
c. Surface area calculated as area of a right circular cylinder.
d. To convert square millimeters to square inches, multiply by 0.00155.
e. To convert square meters to square feet, multiply by 10.764.

Table I-21. Total exposed surface area of the Alloy-22 rails for all drip shields for the Module 1 inventory.

Component	Number of pieces	Average waste package emplacement length[a] (millimeters)[b]	Width[c] (millimeters)[d]	Thickness[c] (millimeters)[d]	Total surface area per average waste package[e] (square millimeters)[f]	Number of waste packages[c]	Total surface area for repository (square meters)[g]
Rail	2	5,076	115	10	1,370,520	16.631	22,793

a. Emplacement length estimate from DIRS 155393-CRWMS M&O (2000, Attachment V, p. V-2).
b. To convert meters to feet, multiply by 3.2808.
c. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
d. To convert millimeters to inches, multiply by 0.0394.
e. Surface area calculated as sum of areas of wetted surfaces (two rectangles) of angles running along the bottom of both sides of the drip shield.
f. To convert square millimeters to square inches, multiply by 0.00155.
g. To convert square meters to square feet, multiply by 10.764.

Table I-22. Total exposed surface area of the Alloy-22 outer layer of all waste packages for the Module 2 inventory.

Waste package type	Number[a]	Outer diameter[a] (millimeters[b])	Length[a] (millimeters[b])	Surface area[c] (square millimeters[d])	Total surface area (square meters[e])
21 PWR absorber plate	6,733	1,664	5,165	31,349,978	211,079
21 PWR control rods	114	1,664	5,165	31,349,978	3,574
12 PWR absorber plate	390	1,330	5,651	26,390,258	10,292
44 BWR absorber plate	4,408	1,674	5,165	31,564,675	139,137
24 BWR thick absorber plate	109	1,318	5,105	23,866,529	2,601
5 DHLW/DOE SNF	1,557	2,110	3,590	30,790,593	47,941
5 DHLW/DOE SNF–long	2,821	2,110	5,217	41,575,586	117,285
Navy SNF	200	1,949	5,430	39,214,523	7,843
Navy SNF–long	100	1,949	6,065	43,102,606	4,310
Navy–long (GTCC and SPAR)[f]	601	1,949	6,065	43,102,606	25,905
2 MCO/2 DHLW	199	1,815	5,217	34,921,842	6,949
Totals	***17,232***				***576,917***

a. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
b. To convert millimeters to inches, multiply by 0.0394.
c. Surface area calculated as area of a right circular cylinder.
d. To convert square millimeters to square inches, multiply by 0.00155.
e. To convert square meters to square feet, multiply by 10.764.
f. Navy SNF-long type waste packages used to represent disposal of Greater-Than-Class-C (GTCC) and Special-Performance-Assessment-Required (SPAR) waste.

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Table I-23. Total exposed surface area of the Alloy-22 rails for all drip shields for the Module 2 inventory.

Component	Number of pieces	Average waste package emplacement length[a] (millimeters)[b]	Width[c] (millimeters)[d]	Thickness[c] (millimeters)[d]	Total surface area per average waste package[e] (square millimeters)[f]	Number of waste packages[c]	Total surface area for repository (square meters)[g]
Rail	2	5,076	115	10	1,370,520	17,232	23,617

a. Emplacement length estimate from DIRS 155393-CRWMS M&O (2000, Attachment V, p. V-2).
b. To convert meters to feet, multiply by 3.2808.
c. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
d. To convert millimeters to inches, multiply by 0.0394.
e. Surface area calculated as sum of areas of wetted surfaces (two rectangles) of angles running along the bottom of both sides of the drip shield.
f. To convert square millimeters to square inches, multiply by 0.00155.
g. To convert square meters to square feet, multiply by 10.764.

Table I-24. Total exposed surface area of the Alloy-22 components for all emplacement pallets under the Proposed Action, Module 1, and Module 2 inventories.

Emplacement pallet component[a]	Number of pieces[a]	Length[a] (millimeters)[b]	Width[a] (millimeters)	Number of sides[a]	Total surface area per pallet (square meters)[c]	Number of pallets[d]	Total surface area repository (square meters)[c]
Plate 1	2	1,845	552.4	1	4.077[e]		
Plate 2	2	922.5	614	2	2.266[f]		
Plate 3	2				2.219[g]		
Plate 4	4	552	462	2	2.040[h]		
Plate 5	4	552	80	2	0.353[i]		
Plate 6	4	1,266.7	603.2	2	6.113[j]		
Plate 7	4	152.4	79.9	2	0.049[k]		
Plate 8	4	152.4	552.4	1	0.337[l]		
Totals for Proposed Action					***17.45***	***11,301***	***197,240***
Totals for Inventory Module 1					***17.45***	***16,631***	***290,266***
Totals for Inventory Module 2					***17.45***	***17,232***	***300,756***

a. Emplacement pallet details from sketches SK-0189 Rev 0 and SK-0144 Rev 1, DIRS 150558-CRWMS M&O (2000).
b. To convert millimeters to inches, multiply by 0.0394.
c. To convert square meters to square feet, multiply by 10.764.
d. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
e. Calculated for one wetted rectangular side.
f. Calculated for both wetted rectangular sides.
g. Surface area equal to that of Plate 2 less area covered by 5.1-centimeter (2.0-inch) tube cross-sections.
h. Calculated assuming rectangular area covered by tubes is not wetted; note that while the inside and outside are covered by tubes the width dimension is correct for each side.
i. Calculated assuming rectangular wetted area.
j. Calculated assuming wetted area includes exposed edge thicknesses which are added to the length and width
k. Calculated based on triangular area.
l. Calculated assuming one wetted side only (because it is covered by the tube).

The sum of exposed total surface areas for waste packages, drip shield rails, and emplacement pallet components fabricated from Alloy-22 (from Tables I-18, I-19, and I-24) is 586,612 square meters (6,314,240 square feet) under the Proposed Action. For Inventory Module 1, the sum of exposed total surface areas (from Tables I-20, I-21, and I-24) is 864,072 square meters (9,300,794 square feet). For Inventory Module 2, the sum of exposed total surface areas (from Tables I-22, I-23, and I-24) is 901,290 square meters (9,701,400 square feet). This is the area of Alloy-22 subject to generalized corrosion under the assumptions outlined for this bounding impact estimate.

Tables I-25, I-26, and I-27 summarize the calculation of the total exposed surface areas for stainless steel 316NG used in the emplacement pallets for the Proposed Action, Module 1, and Module 2 inventories, respectively.

Table I-25. Total exposed surface area of the stainless-steel 316NG components for all emplacement pallets under the Proposed Action inventory.

Emplacement pallet tubes	Number of pieces[a]	Length[a] (millimeters[b])	Width[a] (millimeters)	Number of sides[a]	Total surface area per average waste package[c] (square meters[d])	Number of waste packages[e,f]	Total surface area repository (square meters)
Long pallets	4	4,147	609.6	2	18.877[f]	9,709	183,278
Short pallets	4	2,500	609.6	2	10.845[g]	1,592	17,265
Totals						***11,301***	***200,543***

a. Emplacement pallet details from sketches SK-0189 Rev 0 and SK-0144 Rev 1 (DIRS 150558-CRWMS M&O 2000).
b. To convert millimeters to inches, multiply by 0.0394.
c. Calculated for area of all wetted rectangular sides.
d. To convert square meters to square feet, multiply by 10.764.
e. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
f. Only waste packages of type "5 DHLW/DOE SNF" are assumed to utilize short pallets.

Table I-26. Total exposed surface area of the stainless-steel 316NG components for all emplacement pallets for the Module 1 inventory.

Emplacement pallet tubes	Number of pieces[a]	Length[a] (millimeters[b])	Width[a] (millimeters)	Number of sides[a]	Total surface area per average waste package[c] (square meters[d])	Number of waste packages[e,f]	Total surface area repository (square meters)
Long pallets	4	4,147	609.6	2	18.877[f]	15,075	284,533
Short pallets	4	2,500	609.6	2	10.845[g]	1,557	16,886
Totals						***16,632***	***301,419***

a. Emplacement pallet details from sketches SK-0189 Rev 0 and SK-0144 Rev 1 (DIRS 150558-CRWMS M&O 2000).
b. To convert millimeters to inches, multiply by 0.0394.
c. Calculated for area of all wetted rectangular sides.
d. To convert square meters to square feet, multiply by 10.764.
e. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
f. Only waste packages of type "5 DHLW/DOE SNF" are assumed to utilize short pallets.

Table I-27. Total exposed surface area of the stainless-steel 316NG components for all emplacement pallets for the Module 2 inventory.

Emplacement pallet tubes	Number of pieces[a]	Length[a] (millimeters[b])	Width[a] (millimeters)	Number of sides[a]	Total surface area per average waste package[c] (square meters[d])	Number of waste packages[e,f]	Total surface area repository (square meters)
Long pallets	4	4,147	609.6	2	18.877[f]	15,675	295,899
Short pallets	4	2,500	609.6	2	10.845[g]	1,557	16,886
Totals						***17,232***	***312,785***

a. Emplacement pallet details from sketches SK-0189 Rev 0 and SK-0144 Rev 1 (DIRS 150558-CRWMS M&O 2000).
b. To convert millimeters to inches, multiply by 0.0394.
c. Calculated for area of all wetted rectangular sides.
d. To convert square meters to square feet, multiply by 10.764.
e. Waste package data from DIRS 150558-CRWMS M&O (2000, all).
f. Only waste packages of type "5 DHLW/DOE SNF" are assumed to utilize short pallets.

I.6.2.3 General Corrosion Rates

The general corrosion rate for Alloy-22 has been measured in laboratory experiments. The corrosion rate was input to the TSPA model as a cumulative distribution function. The 5th percentile is 0.000012 millimeter (0.0000004 inch) per year, the median value is 0.000045 millimeter (0.0000017 inch) per year, and the 95th-percentile of the distribution is 0.00008 millimeter (0.000003 inch) per year (DIRS 152542-CRWMS M&O 2000, Figure 1, p. 11). For purposes of this bounding calculation, the median rate was chosen because the calculation is concerned with the average rate of corrosion over a large number of waste packages, drip shield rails, and emplacement pallets. Hence, the median rate is representative of repository conditions taken as a whole over the 10,000-year post-closure period.

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The median general corrosion rate for stainless steel 316NG is 0.01 micron per year (0.0000394 inch per year) (DIRS 135968-CRWMS M&O 2000, Figure 3-15, p. 3-30).

I.6.2.4 Release Rates

The rate of release of waterborne chemically toxic materials was calculated as the product of the surface area exposed to general corrosion, the general corrosion rate, and the weight fraction of the alloy for the waterborne chemically toxic material of interest. Alloy-22 is comprised of among other elements, 22.5 percent (maximum) chromium, 14.5 percent (maximum) molybdenum, 57.2 percent nickel, and 0.35 percent vanadium (DIRS 104328-ASTM 1998, all). Stainless steel 316NG is assumed to be essentially the same as 316L, which is comprised, among other elements, of 17.0 percent chromium, 12 percent nickel, and 2.5 percent molybdenum with no vanadium (DIRS 102933-CRWMS M&O 1999, p. 13).

Tables I-28, I-29, and I-30 summarize the calculation of the bounding mass release rates for the Proposed Action, Module 1, and Module 2 inventories, respectively. The mass release rates for chromium, molybdenum, nickel, and vanadium are based on the surface exposure area of exposed repository components containing these elements, the general corrosion rates for those components, and the weight percent content of the individual elements.

Table I-28. Bounding mass release rates (grams per year)[a] from Alloy-22 and stainless-steel 316NG components from general corrosion for the Proposed Action.

Alloy	Total exposed surface area in repository (square meters)[b]	General corrosion rate (meters per year)[c]	Alloy release volume (cubic meter per year)[d]	Alloy density (grams per cubic meter)[e]	Bounding mass release rate (grams per year)[a]				
					Alloy	Chromium	Molybdenum	Nickel	Vanadium
Alloy-22	586,612	4.5×10^{-8}	0.0264	8,690,000	229,395	51,614	33,262	131,099	803
316NG	200,543	1.0×10^{-8}	0.00201	7,980,000	16,003	2,721	400	1,920	0
Totals						***54,334***	***33,662***	***133,019***	***803***

a. To convert grams to ounces, multiply by 0.035273.
b. To convert square meters to square feet, multiply by 10.764.
c. To convert meters to feet, multiply by 3.2468.
d. To convert cubic meters to cubic feet, multiply by 35.314.
e. To convert grams per cubic meter to ounces per cubic foot, multiply by 0.0010047.

Table I-29. Bounding mass release rates (grams per year)[a] from Alloy-22 and stainless-steel 316NG components from general corrosion for Module 1.

Alloy	Total exposed surface area in repository (square meters)[b]	General corrosion rate (meters per year)[c]	Alloy release volume (cubic meter per year)[d]	Alloy density (grams per cubic meter)[e]	Bounding mass release rate (grams per year)[a]				
					Alloy	Chromium	Molybdenum	Nickel	Vanadium
Alloy-22	864,072	4.5×10^{-8}	0.0389	8,690,000	337,895	76,026	48,995	193,107	1,183
316NG	312,785	1.0×10^{-8}	0.0030	7,980,000	24,055	4,089	601	2,887	0
Totals						***80,116***	***49,596***	***195,994***	***1,183***

a. To convert grams to ounces, multiply by 0.035273.
b. To convert square meters to square feet, multiply by 10.764.
c. To convert meters to feet, multiply by 3.2468.
d. To convert cubic meters to cubic feet, multiply by 35.314.
e. To convert grams per cubic meter to ounces per cubic foot, multiply by 0.0010047.

I.6.2.5 Summary of Bounding Impacts

The bounding maximum concentration is based on the general corrosion rate of the source materials and the representative volume for dilution prescribed in the final Environmental Protection Agency regulation 40 CFR Part 197. Diluting the bounding release rates presented in Section I.6.2.4 for chromium, molybdenum, nickel, and vanadium in the prescribed representative volume of water (3.7 million cubic meters, or exactly 3,000 acre-feet per year) used for calculation of groundwater protection impacts for

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Table I-30. Bounding mass release rates (grams per year)[a] from Alloy-22 and stainless-steel 316NG components from general corrosion for Module 2.

Alloy	Total exposed surface area in repositoy (square meters)[b]	General corrosion rate (meters per year)[c]	Alloy release volume (cubic meter per year)[d]	Alloy density (grams per cubic meter)[e]	Bounding mass release rate (grams per year)[a]				
					Alloy	Chromium	Molybdenum	Nickel	Vanadium
Alloy-22	901,290	4.5×10^{-8}	0.0406	8,690,000	352,450	79,301	51,105	201,425	1,233
316NG	312,785	1.0×10^{-8}	0.0031	7,980,000	24,960	4,243	624	2,995	0
Totals						***83,544***	***51,729***	***204,420***	***1,233***

a. To convert grams to ounces, multiply by 0.035273.
b. To convert square meters to square feet, multiply by 10.764.
c. To convert meters to feet, multiply by 3.2468.
d. To convert cubic meters to cubic feet, multiply by 35.314.
e. To convert grams per cubic meter to ounces per cubic foot, multiply by 0.0010047.

waterborne radioactive materials results in the bounding concentration in groundwater at exposure locations for these chemically toxic materials listed in Table I-31.

Table I-31. Bounding concentrations of waterborne chemical materials of concern compared to Maximum Contaminant Levels Goals (milligrams per liter).

Material	Maximum Contaminant Level Goal	Maximum bounding concentration		
		Proposed Action	Inventory Module 1	Inventory Module 2
Chromium (VI)	0.1[a]	0.015	0.022	0.023
Molybdenum	NA[b]	0.009	0.013	0.014
Nickel	NA	0.036	0.053	0.055
Vanadium	NA	0.00022	0.00032	0.00033

a. 40 CFR 141.51.
b. NA = not available.

There are two measures for comparing human health effects for chromium. When the Environmental Protection Agency established its Maximum Contaminant Level Goals, it considered safe levels of contaminants in drinking water and the ability to achieve these levels with the best available technology. The Maximum Contaminant Level Goal for chromium is 0.1 milligram per liter (40 CFR 141.51). The bounding concentrations for the Proposed Action and for Inventory Modules 1 and 2 (Table I-31) are well below the Maximum Contaminant Level Goal for chromium. The other measure for comparison is the Oral Reference Dose for chromium, which is 0.005 milligram per kilogram of body mass per day (DIRS 148224-EPA 1999, all). The reference dose factor represents a level of intake that has no adverse effect on humans. It can be converted to a threshold concentration level for drinking water. The conversion yields essentially the same concentration for the reference dose factor as the Maximum Contaminant Level Goal.

No attempt can be made at present to express the bounding estimate of groundwater concentration of hexavalent chromium in terms of human health effects (for example, latent cancer fatalities). The carcinogenicity of hexavalent chromium by the oral route of exposure cannot be determined because of a lack of sufficient epidemiological or toxicological data (DIRS 148224-EPA 1999, all; DIRS 101825-EPA 1998, p. 48).

There is no Maximum Contaminant Level Goals for molybdenum, nickel, or vanadium. However, we can compare the intake based on the maximum bounding concentrations in Table I-31 to the Oral Reference Dose for each of these materials. The intakes by chemical, assuming water consumption of 2 liters (0.53 gallon) per day by a 70-kilogram (154-pound) person, are listed in Table I-32 along with the relevant Oral Reference Dose. The values in Table I-32 show that the intakes are well below the respective Oral Reference Doses for chromium, molybdenum, nickel, and vanadium for the Proposed Action, Inventory Modules 1, and Inventory Module 2.

Table I-32. Summary of intake of waterborne chemical materials of concern based on maximum bounding concentrations listed in Table I-31 compared to Oral Reference Doses.

Material	Oral Reference Dose	Intake[a]		
		Proposed Action	Inventory Module 1	Inventory Module 2
Chromium (VI)	0.005[b]	0.00042	0.00062	0.00065
Molybdenum	0.005[c]	0.00026	0.00038	0.00040
Nickel	0.02[d]	0.0010	0.0015	0.0016
Vanadium	0.007[e]	0.0000062	0.0000091	0.000010

a. Assuming daily intake of 2.0 liters (0.53 gallon) per day by a 70-kilogram (154-pound) individual.
b. DIRS 148224-EPA 1999, all.
c. DIRS 148228-EPA 1999, all.
d. DIRS 148229-EPA 1999, all.
e. DIRS 103705-EPA 1997, all.

Because the bounding concentration of chromium, molybdenum, nickel, and vanadium in groundwater is calculated to be below the Maximum Contaminant Level Goal or yield intakes well below the respective Oral Reference Doses, there is no further need to refine the calculation to account for physical processes that would limit mobilization of these materials or delay and dilute them during transport in the geosphere.

I.7 Atmospheric Radioactive Material Impacts

Following closure of the proposed Yucca Mountain Repository, there would be limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. Still, the rock is porous and does allow gas to flow, so the analysis must consider possible airborne releases. The only radionuclide that would have a relatively large inventory and a potential for gas transport is carbon-14. Iodine-129 can exist in a gas phase, but it is highly soluble and, therefore, would be more likely to dissolve in groundwater rather than migrate as a gas. Other gas-phase isotopes were eliminated in the screening analysis (Section I.3.3), usually because they have short half-lives and are not decay products of long-lived isotopes. A separate screening argument for radon-222 is provided in Section I.7.3. After carbon-14 escaped from the waste package, it could flow through the rock in the form of carbon dioxide. Atmospheric pathway models were used to estimate human health impacts to the local population in the 80-kilometer (50-mile) region surrounding the repository.

About 2 percent of the carbon-14 in commercial spent nuclear fuel exists as a gas in the space (or *gap*) between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92). The average carbon-14 inventory in a commercial spent nuclear fuel waste package is approximately 1.37 grams (0.048 ounce) (6.11 curies) (see Table I-5), so the analysis used a gas-phase inventory of 0.122 curie of carbon-14 per commercial spent nuclear fuel waste package to calculate impacts from the atmospheric release pathway. The waterborne radioactive materials analysis described in Chapter 5, Section 5.4 included the entire inventory of the carbon-14 in the repository in the groundwater release models. Thus, the groundwater-based impacts would be overestimated slightly (by 2 percent) by this modeling approach.

Carbon is the second-most abundant element (by mass) in the human body, constituting 23 percent of Reference Man (DIRS 101074-ICRP 1975, p. 327). Ninety-nine percent of the carbon comes from food ingestion (DIRS 148066-Killough and Rohwer 1978, p. 141). Daily carbon intakes are approximately 300 grams (0.7 pound) and losses include 270 grams (0.6 pound) exhaled, 7 grams (0.02 pound) in feces, and 5 grams (0.01 pound) in urine (DIRS 101074-ICRP 1975, p. 377).

Carbon-14 dosimetry can be performed assuming specific-activity equivalence. The primary human intake pathway of carbon is food ingestion. The carbon-14 in food results from photosynthetic processing of atmospheric carbon dioxide, whether the food is the plant itself or an animal that feeds on the plant. Biotic systems, in general, do not differentiate between carbon isotopes. Therefore, the carbon-14 activity concentration in the atmosphere will be equivalent to the carbon-14 activity concentration in the plant, which in turn will result in an equivalent carbon-14 specific activity in human tissues.

I.7.1 CARBON-14 RELEASES TO THE ATMOSPHERE

The calculation of regional radiological doses requires estimation of the annual release rate of carbon-14. The analysis based the carbon-14 release rate on the estimated timeline of container failures for the higher-temperature repository operating mode, using the time-dependent mean value of the number of failed waste packages. The expected number of commercial spent nuclear fuel waste package failures in 100-year intervals was used to estimate the carbon-14 release rate after repository closure. The estimated amount of material released from each package as a function of time was reduced to account for radiological decay.

As for the waterborne radioactive material releases described in Chapter 5, Section 5.4, credit was taken for the intact zirconium-alloy cladding (on approximately 99 percent by volume of the commercial spent nuclear fuel at emplacement) delaying the release of gas-phase carbon-14. The remaining 1 percent by volume of the commercial spent nuclear fuel either would have stainless-steel cladding (which degrades much more quickly than zirconium alloy) or would already have failed in the reactor. The cladding failure submodel of the TSPA model also estimates the time of the first perforation through the cladding. Because carbon-14 in gas form as carbon dioxide can migrate through small holes, the time of first perforation was used as the time of release from the carbon-14 from the failed fuel element. A plot of the fraction of the cladding that has been perforated as a function of time after repository closure is shown in Figure I-27.

The amount (in curies) of carbon-14 that would be available for transport, A_T, from a waste package at the time it fails is calculated as:

$$A_T = D_F \times F_{FC} \times 0.122 \text{ curies per package}$$

where:

D_F = Time-dependent factor that accounts for radioactive decay (unitless)

F_{FC} = Fraction of perforated cladding (unitless)

The analysis technique calculated the above quantity on a time interval of every 100 years. At each time interval, the amount of carbon-14, B_T, available for transport due to further cladding perforations in waste packages that failed previously was also calculated. This amount was calculated as follows:

$$B_T = D_F \times DF_{FC} \times N_{PF} \times 0.122 \text{ curies per package}$$

where:

DF_{FC} = Fraction of cladding that was perforated in the 100-year time interval (unitless)

N_{PF} = Number of waste packages that had failed prior to the current 100-year time interval (unitless)

Rather than conducting a detailed gas-flow model of the mountain, the analysis assumed that the carbon-14 from the failed waste package would be released to the ground surface uniformly over a

100-year interval. Thus, the release rate (curies per year) to the ground surface, G_S, for a time interval was calculated as follows:

$$G_S = (N_{CI} \times A_T + B_T) / 100$$

where:

N_{CI} = Number of waste packages that failed in the current 100-year time interval (unitless)

Figure I-28 shows the estimated release rate of carbon-14 from the repository for 80,000 years after repository closure, assuming that the commercial spent nuclear fuel with perforated cladding had released its gas-phase carbon-14 prior to being placed in a waste package. The results in Figure I-28 are based on the Proposed Action inventory. Each symbol in the figure represents the carbon-14 release rate to the ground surface for a period of 100 years. The general downward slope of the symbols is due to radioactive decay (carbon-14 has a half-life of 5,730 years). The symbols indicating near-zero releases (curies per year) indicate that no waste packages failed during some 100-year periods, and the fraction of perforated cladding changed only a small amount. Using this expected-value representation of waste package lifetime, only 1 of 7,860 commercial spent nuclear fuel waste packages would have failed during the first 10,000 years after repository closure. See Section I.2.4 for a description of early waste package failure mechanisms. The second waste package would fail at about 53,000 years after repository closure. By 80,000 years after repository closure, 131 of the 7,860 commercial spent nuclear fuel waste packages would have failed. Using this expected-value representation of the time of first cladding perforation, about 2 percent of the cladding would be perforated in the first 10,000 years. Thus, all releases prior to 50,000 years on Figure I-28 come from a single waste package. The maximum release rate would occur about 1,700 years after repository closure. The estimated maximum release rate would be about 3.3 microcurie per year.

For Inventory Module 1, the number of idealized waste packages containing commercial spent nuclear fuel would increase from 7,860 to 11,754. Using the expected value curves for waste package failure, there would only be 1 waste package failure in the first 10,000 years for Inventory Module 1. Even though the modeled time of the waste package failure is 100 years earlier than for the Proposed Action inventory, the expected value for the fraction of cladding perforated is nearly identical for the two inventory modules during the first 10,000 years. Thus, the maximum release rate to the ground surface is the same and occurs at the same time for both inventory modules. Inventory Module 2 would not add any additional materials expected to contain gas-phase carbon-14, so it would have the same maximum release rate to the ground surface as the Proposed Action inventory.

I.7.2 ATMOSPHERE CONSEQUENCES TO THE LOCAL POPULATION

DOE used the GENII program (DIRS 100953-Napier et al. 1998, all) to model the atmospheric transport and human uptake of released carbon-14 for the 80-kilometer (50-mile) population radiological dose calculation. Radiological doses to the regional population near Yucca Mountain from carbon-14 releases were estimated using the population distribution described in Appendix G, Section G.2.1, which indicates approximately 76,000 people would live in the region surrounding Yucca Mountain in 2035. The population by distance and sector used in the calculations are listed in Table G-48. The computation also used current (1993 to 1996) annual average meteorology. The joint frequency data are listed in Table I-33.

A population radiological dose factor of 4.6×10^{-9} person-rem per microcurie per year of release was calculated using the GENII code. For a 3.3-microcurie-per-year maximum release rate, an 80-kilometer (50-mile) population radiological dose rate would be 1.5×10^{-8} person-rem per year. This radiological dose rate represents 7.5×10^{-12} latent cancer fatality in the regional population of 76,000 persons each

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Table I-33. Meteorologic joint frequency data used for Yucca Mountain atmospheric releases (percent of time).[a]

Average wind speed (m/s)[b]	Atmospheric stability class	Direction (wind toward)															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.9	A	0.807	0.633	0.613	0.520	0.462	0.604	0.688	0.659	0.467	0.340	0.183	0.200	0.197	0.212	0.412	0.778
	B	0.279	0.479	0.392	0.325	0.372	0.540	1.243	2.279	1.484	0.499	0.290	0.192	0.105	0.070	0.087	0.305
	C	0.113	0.105	0.064	0.017	0.015	0.020	0.041	0.157	0.122	0.067	0.055	0.020	0.012	0.020	0.009	0.032
	D	0.003	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.55	A	0.099	0.073	0.026	0.020	0.026	0.017	0.023	0.061	0.041	0.029	0.023	0.017	0.029	0.029	0.052	0.096
	B	0.058	0.044	0.038	0.026	0.032	0.061	0.125	0.377	0.360	0.070	0.049	0.015	0.009	0	0.009	0.017
	C	0.229	0.267	0.256	0.116	0.110	0.105	0.328	1.193	2.404	0.909	0.671	0.302	0.157	0.142	0.125	0.174
	D	0.105	0.049	0.038	0.003	0.003	0.003	0.006	0.035	0.444	0.290	0.206	0.055	0.035	0.049	0.087	0.099
	E	0.003	0.006	0	0.003	0	0	0.003	0.003	0.003	0.006	0.003	0.003	0.003	0.003	0	0.003
	F	0	0.003	0	0	0	0	0	0	0.003	0.003	0	0	0	0	0	0.003
4.35	A	0.096	0.096	0.041	0.015	0.012	0.009	0.015	0.023	0.058	0.044	0.026	0.023	0.029	0.020	0.020	0.070
	B	0.052	0.087	0.041	0.023	0.006	0.026	0.078	0.261	0.305	0.131	0.076	0.017	0.006	0.003	0.009	0.032
	C	0.142	0.241	0.168	0.070	0.029	0.076	0.131	0.740	1.638	0.308	0.290	0.119	0.049	0.041	0.038	0.102
	D	0.253	0.264	0.163	0.049	0.020	0.020	0.020	0.392	2.375	0.447	0.285	0.081	0.046	0.058	0.139	0.346
	E	0.006	0.017	0	0	0	0	0	0.003	0.006	0.020	0.015	0.006	0.003	0.003	0.012	0.020
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.95	A	1.568	0.642	0.215	0.038	0.035	0.009	0.023	0.026	0.081	0.142	0.261	0.163	0.209	0.314	0.343	0.819
	B	0.682	0.552	0.067	0.003	0.006	0.006	0.023	0.058	0.348	0.325	0.267	0.131	0.078	0.093	0.078	0.256
	C	0.993	0.560	0.105	0.012	0.009	0.078	0.090	0.244	0.984	0.526	0.337	0.192	0.067	0.076	0.073	0.189
	D	1.594	0.912	0.183	0.020	0.020	0.006	0.035	0.566	3.368	0.430	0.160	0.128	0.035	0.044	0.142	0.598
	E	0.735	0.366	0.067	0.012	0.006	0	0	0.386	2.515	0.192	0.038	0.015	0	0.015	0.064	0.804
	F	0.238	0.096	0.003	0	0.003	0	0	0.142	1.641	0.055	0.032	0	0.003	0.003	0.029	0.796
9.75	A	2.134	0.935	0.218	0.078	0.029	0.041	0.026	0.070	0.163	0.232	0.203	0.232	0.267	0.372	0.587	1.388
	B	0.865	0.627	0.081	0.009	0.003	0.017	0.020	0.046	0.319	0.267	0.154	0.131	0.070	0.052	0.113	0.302
	C	0.720	0.261	0.038	0.012	0.020	0.020	0.009	0.076	0.502	0.299	0.148	0.229	0.078	0.032	0.041	0.157
	D	0.415	0.212	0.020	0.003	0.003	0.003	0.003	0.046	0.627	0.154	0.044	0.032	0.029	0.009	0.026	0.145
	E	0.029	0.006	0	0	0.003	0	0	0	0.006	0.003	0.003	0	0	0.003	0	0.003
	F	0	0.003	0	0	0	0	0	0	0	0	0	0	0	0.003	0	0.003
12.98	A	1.661	0.706	0.418	0.322	0.247	0.244	0.366	0.343	0.407	0.380	0.302	0.299	0.357	0.537	1.083	2.038
	B	0.836	0.668	0.253	0.107	0.157	0.116	0.264	0.499	0.674	0.404	0.270	0.171	0.122	0.096	0.232	0.950
	C	0.322	0.267	0.087	0.017	0.006	0.012	0.026	0.136	0.311	0.107	0.032	0.029	0.020	0.009	0.015	0.038
	D	0.006	0.006	0	0	0	0	0	0.003	0.012	0.003	0	0	0	0	0	0.003
	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

a. Source: Adapted from data in DIRS 102877-CRWMS M&O (1999, Appendix B, all).

b. m/s = meters per second; to convert meters per second to miles per hour, multiply by 2.237.

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year at the maximum release rate. This annual population radiological dose rate corresponds to a lifetime radiological population dose of 1.1×10^{-6} rem (assuming a 70-year lifetime), which corresponds to 5.3×10^{-10} latent cancer fatality during the 70-year period of the maximum release.

The impacts were also calculated for a maximally exposed individual. Given the population data in Appendix G, Table G-48 and the joint frequency data in Table I-33, the maximally exposed individual would reside 24 kilometers (15 miles) south of the repository. An individual radiological dose factor of 5.6×10^{-14} rem per microcurie per year of release was calculated using the GENII code for this location. For a 3.3-microcurie-per-year maximum release rate, the individual maximum radiological dose rate would be 1.8×10^{-13} rem per year, corresponding to a 9.2×10^{-17} probability of a latent cancer fatality. The 70-year lifetime dose would be 1.3×10^{-11} rem, representing a 6.4×10^{-15} probability of a latent cancer fatality.

I.7.3 SCREENING ARGUMENT FOR RADON

The uranium placed in the repository would continuously produce radon as a decay product. The longest-lived radon isotope is radon-222, with a half-life of 4 days (DIRS 103178-Lide and Frederikse 1997, p. 4-24). The only potential transport and human exposure pathway for radon would be through the atmosphere because radon would not travel far enough in water to reach an individual before decaying.

A study performed by Y.S. Wu and others (DIRS 103690-Wu, Chen, and Bodvarsson 1995, all) at Lawrence Berkeley National Laboratory calculated gas and heat flow from the mountain due to steam formation and repository induced heating. This study calculated heat and mass fluxes for 57- and 114-kilowatt-per-acre emplacements. The study indicated maximum gas fluxes at the surface of about 2×10^{-7} kilogram per second per square meter at the Ghost Dance and Solitario Canyon faults and generally no more that 2×10^{-9} kilogram per second per square meter over the remainder of the surface.

The gas flux at the Ghost Dance fault was used to estimate a lower limit for the gas travel time after the waste packages began to fail. The travel times would be longer for a smaller thermal gradient and most waste packages are estimated to remain intact until long after the thermal gradient from the waste emplacement had declined to almost zero. However, this calculation still applies if a waste package failed during the period of highest thermal gradient.

A gas pore velocity, using the estimated gas flux for the Ghost Dance Fault, applicable for gas travel from the repository horizon to the surface, is calculated from the following equation:

$$Vp = Fg / (Da \times Rp)$$

where:

Fg = Gas flux (2×10^{-7} kilogram per second per meter squared)

Da = Density of air (approximately 1.2 kilogram per cubic meter at 20º Celsius) (DIRS 127163-Weast 1972, p. F-11)

Rp = Rock porosity (0.082, unitless) (DIRS 100033-Flint 1998, Table 7, p. 44)

Vp = Pore Velocity (meters per second) = 2.03×10^{-6}

Travel time from the repository horizon to the surface is calculated from the following equation:

$$T_t = Rd / (Vp \times 86400)$$

where:

Rd	=	Depth to the repository (approximately 200 meters)
86400	=	Number of seconds per day
T_t	=	Gas travel time (days) = 1,140

Because the radioactive decay constant for radon-222 is 0.18145 (per day), radioactive decay would reduce the amount of radon-222 in the air by approximately 90 orders of magnitude in the time it took the air to travel from the repository horizon up through 200 meters (660 feet) of overlying rock. Therefore, no human effects are anticipated from the atmospheric release of radon-222 in the waste packages.

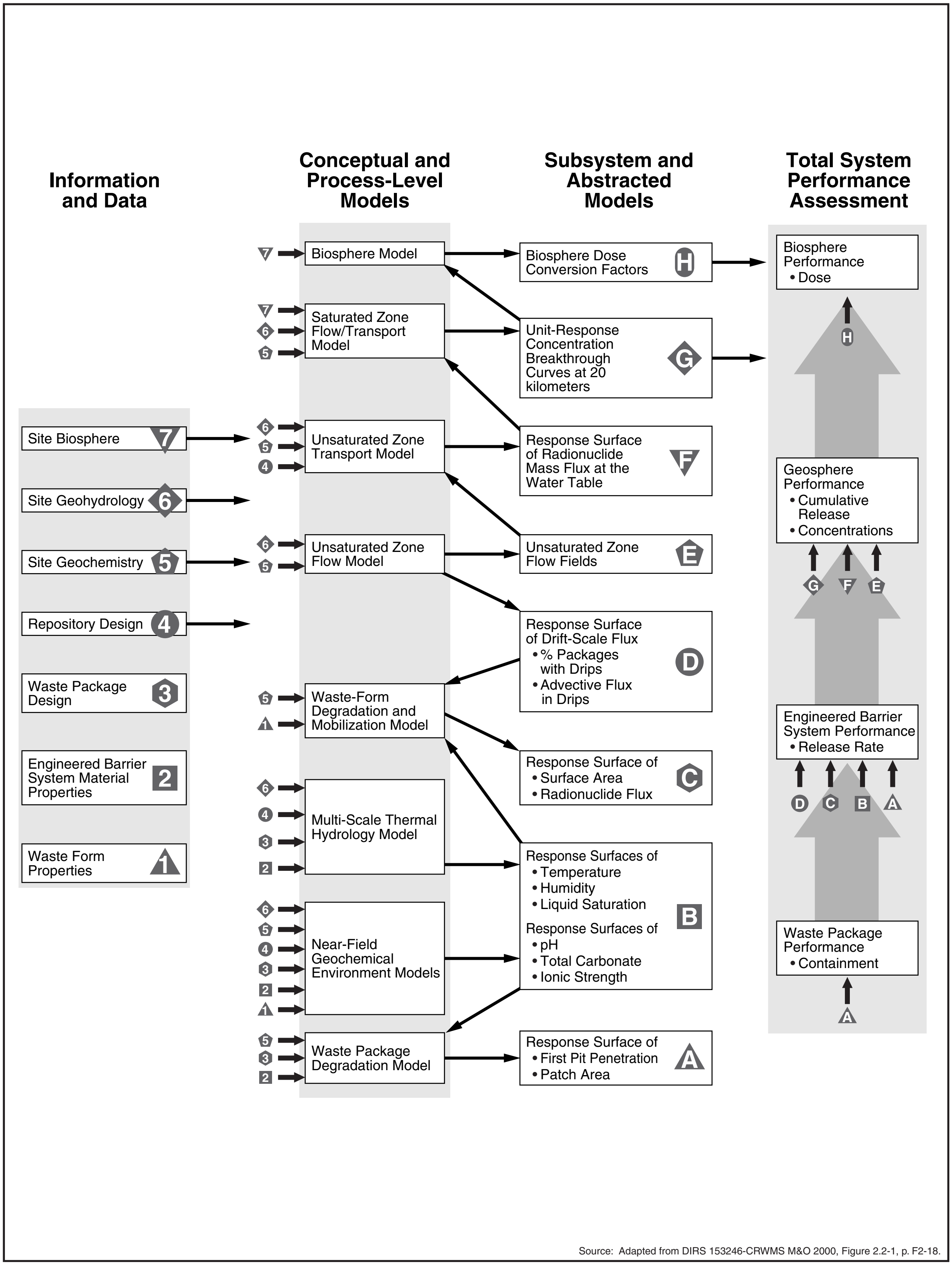


Figure I-1. TSPA model.

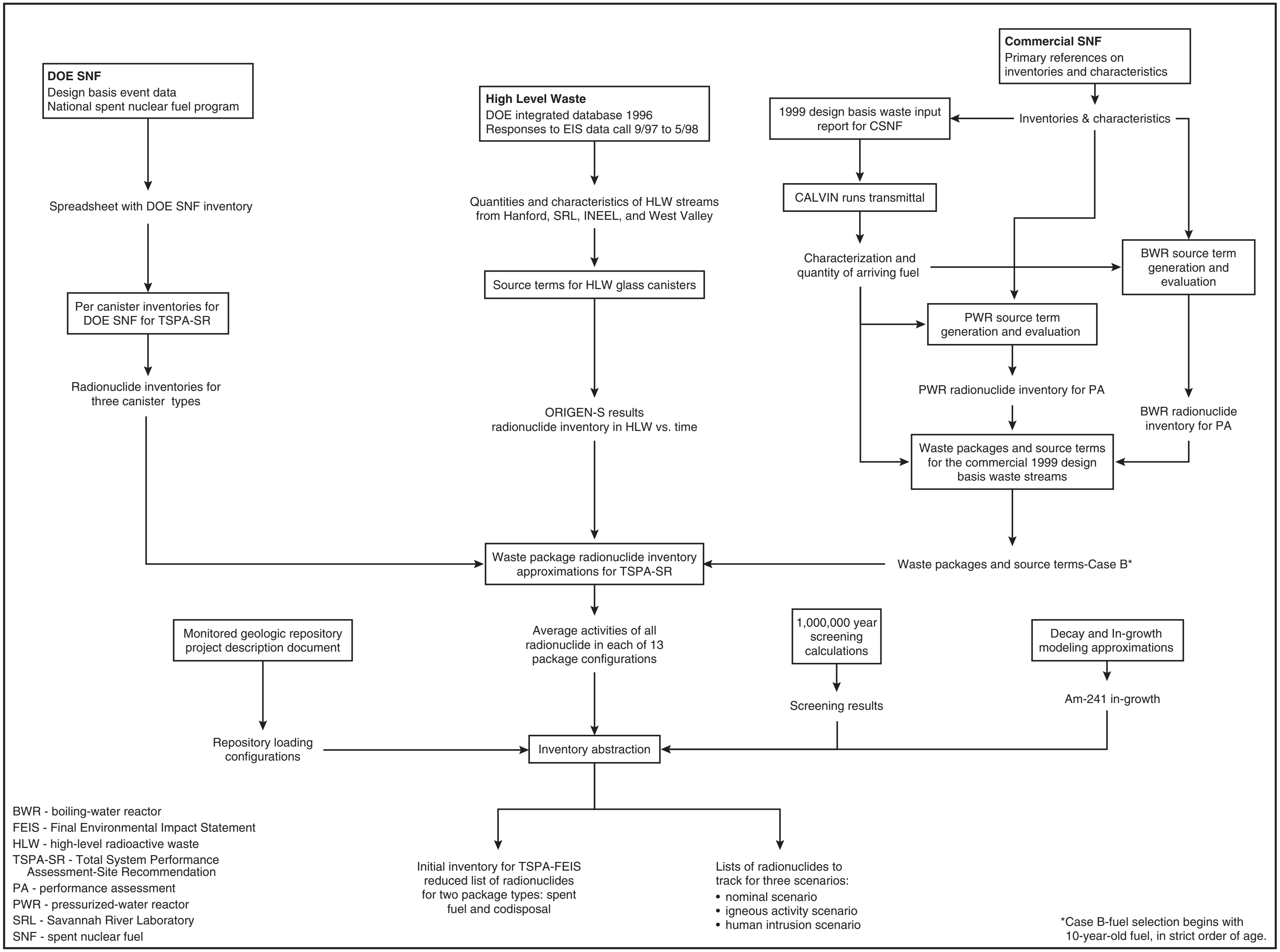


Figure I-2. Development of abstracted inventory for TSPA-FEIS.

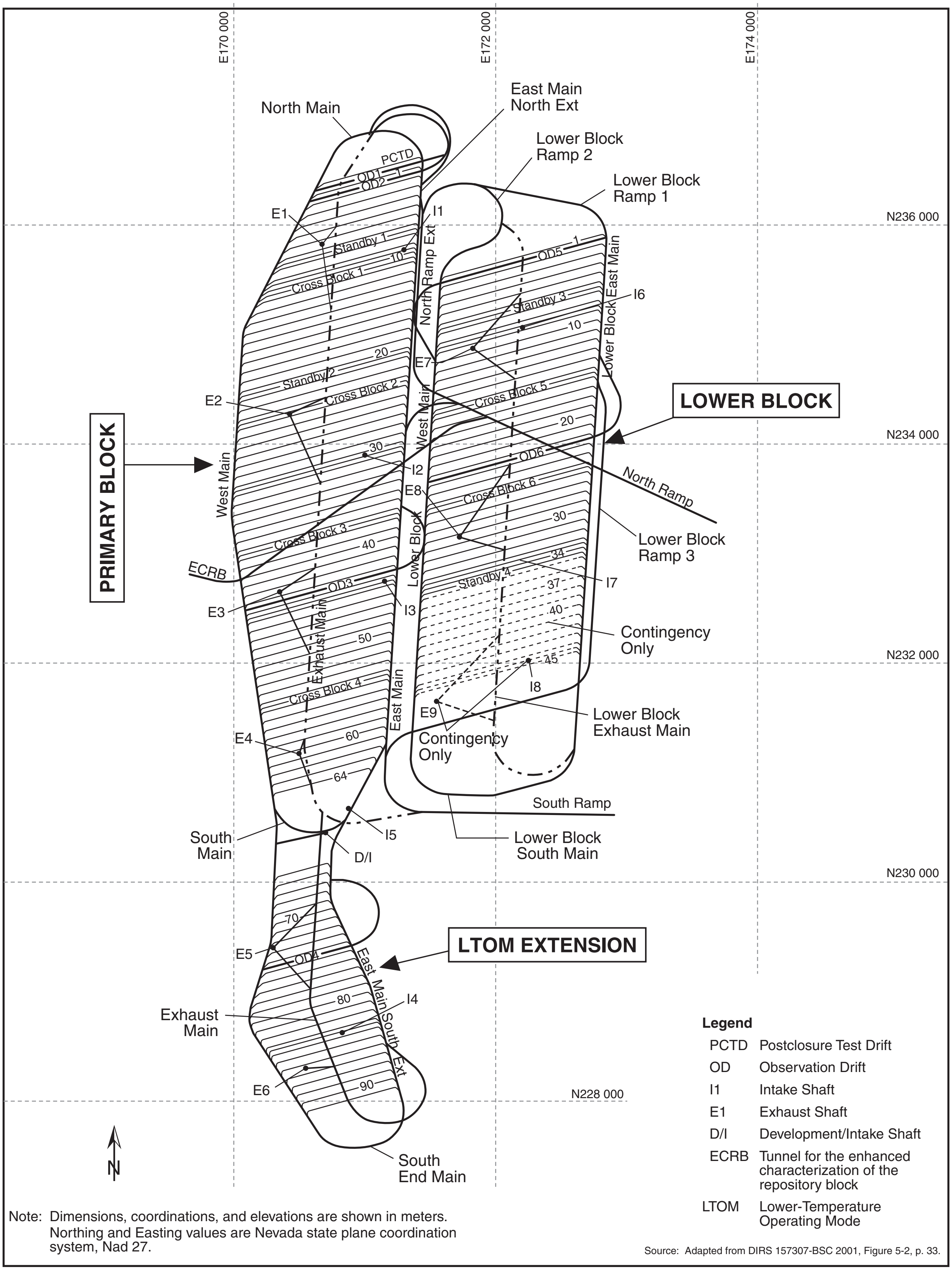
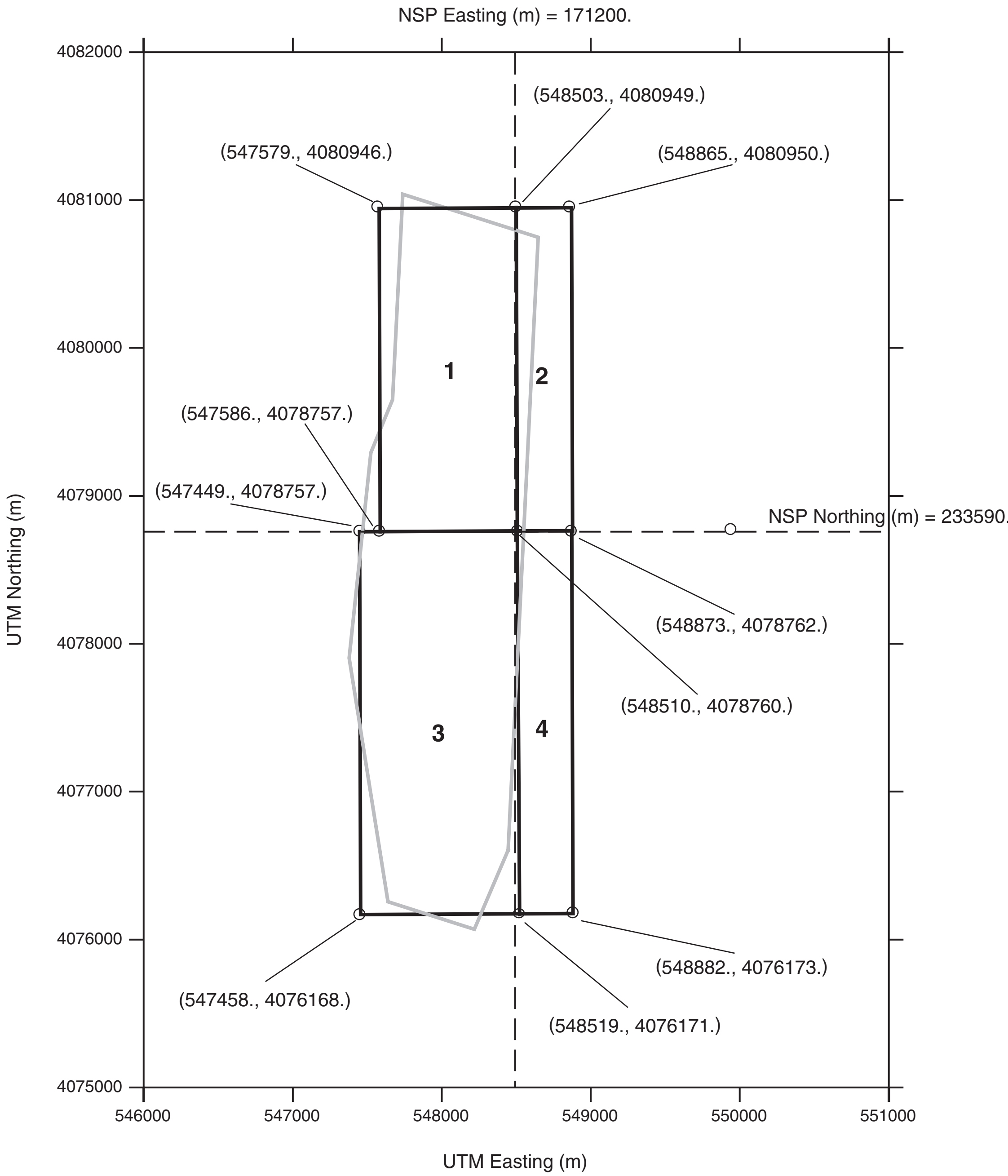


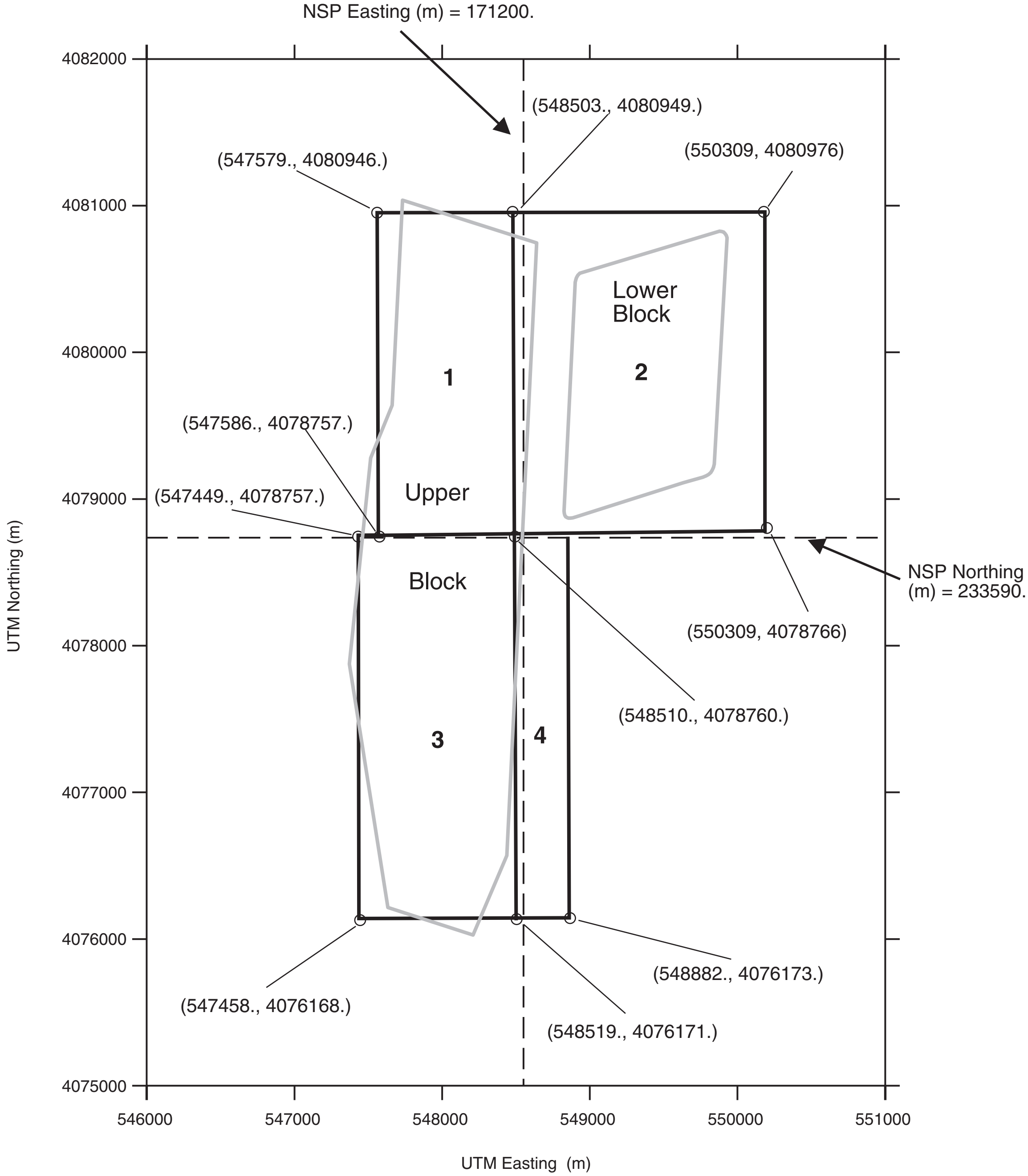
Figure I-3. Approximate configuration of the proposed Yucca Mountain Repository.



Note: Source regions are outlined with the solid black rectangles and numbered from 1 to 4. The coordinates of the vertices of the source region rectangles are given in Universal Transverse Mercator (UTM) coordinates (meters). The outline of the repository is shown by the gray lines. The dashed lines indicate the quadrants from which radionuclide arrivals from the unsaturated zone model are applied to the saturated zone source regions. Coordinates of the dashed lines are given in Nevada State Plan (NSP) coordinates (meters).

Source: Adapted from DIRS 157307-BSC 2001, Figure 5-3, p. 34.

Figure I-4. The four saturated zone capture regions in relation to the primary repository block for the Proposed Action.



Note: Source regions are outlined with the solid black rectangles and numbered from 1 to 4. The coordinates of the vertices of the source region rectangles are given in Universal Transverse Mercator (UTM) coordinates (meters). The outline of the repository is shown by the gray lines. The dashed lines indicate the quadrants from which radionuclide arrivals from the unsaturated zone model are applied to the saturated zone source regions. Coordinates of the dashed lines are given in Nevada State Plan (NSP) coordinates (meters).

Source: Adapted from DIRS 157307-BSC 2001, Figure 5-4, p. I-35.

Figure I-5. The four saturated zone capture regions in relation to the primary and lower repository blocks for Inventory Modules 1 and 2.

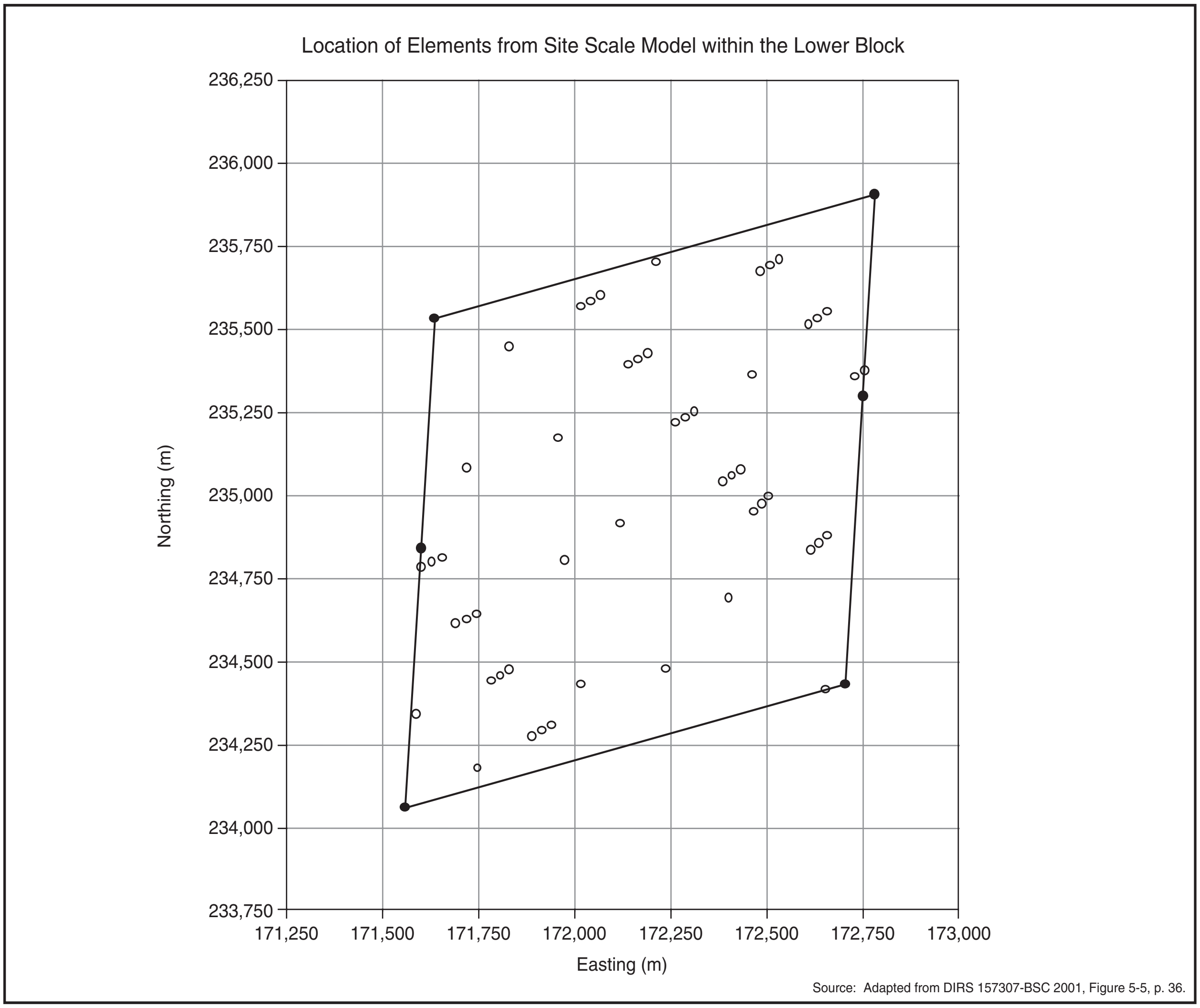


Figure I-6. Outline of the Lower Block showing the locations of the 51 particle-tracking nodes.

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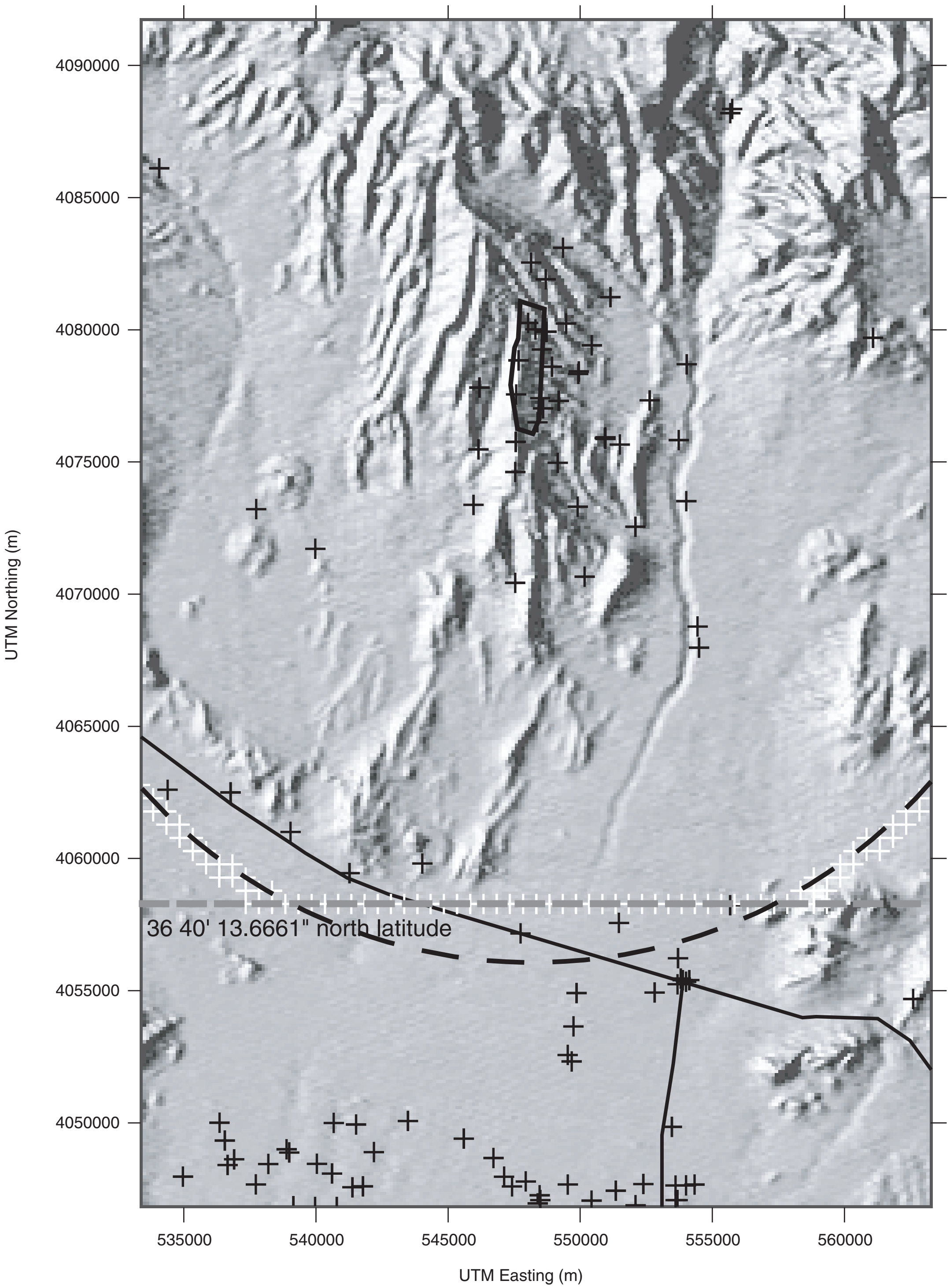


Note: The horizontal dashed line represents the southernmost boundary between the controlled area and accessible environment (36º 40' 13.6661" North latitude as per EPA 40 CFR Part 197). The semicircular dashed line represents the 20-kilometer (12-mile) fence used in the TSPA-SR model to evaluate compliance with the then-proposed Environmental Protection Agency and Nuclear Regulatory Commission regulations. The white crosses represent the saturated zone transport model grid cells at the intersection of the new southernmost boundary with the 20-kilometer fence used in TSPA-SR evaluations. The black crosses are well locations, and the solid black lines represent Highway 95 and Highway 373.

Source: Adapted from DIRS 157307-BSC 2001, Figure 5-6, p. 37.

Figure I-7. Southernmost boundary of the controlled area and the accessible environment.

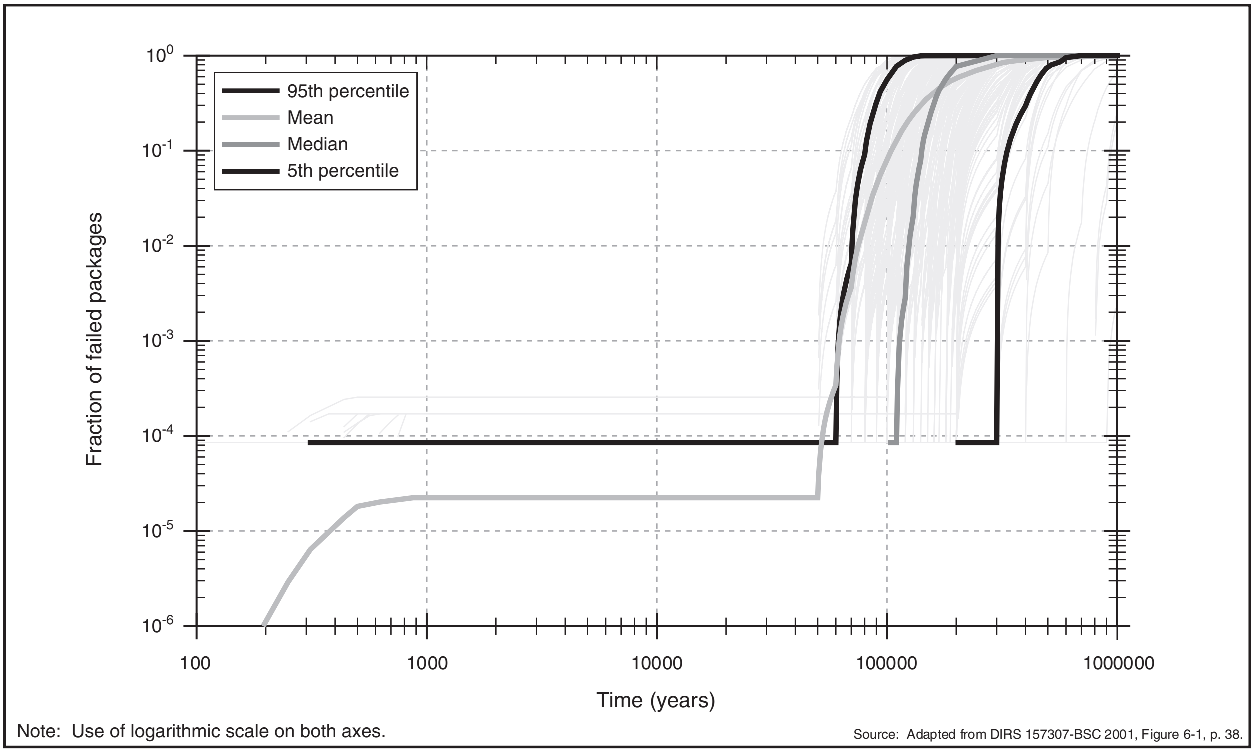


Figure I-8. Waste package failure curves for 300 probabilistic simulations for the Proposed Action inventory; the figure also displays the 5th-percentile, median, mean, and 95th-percentile values of these simulations.

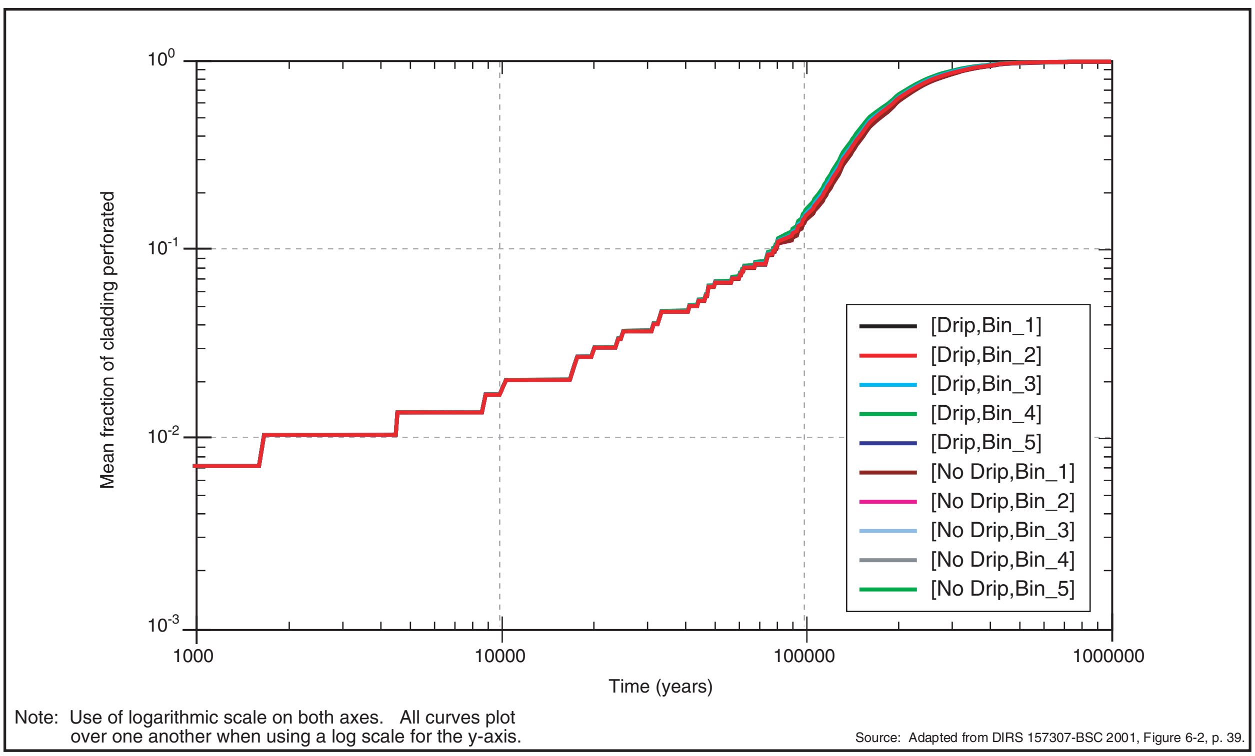


Figure I-9. Cladding failure profile for the Proposed Action inventory.

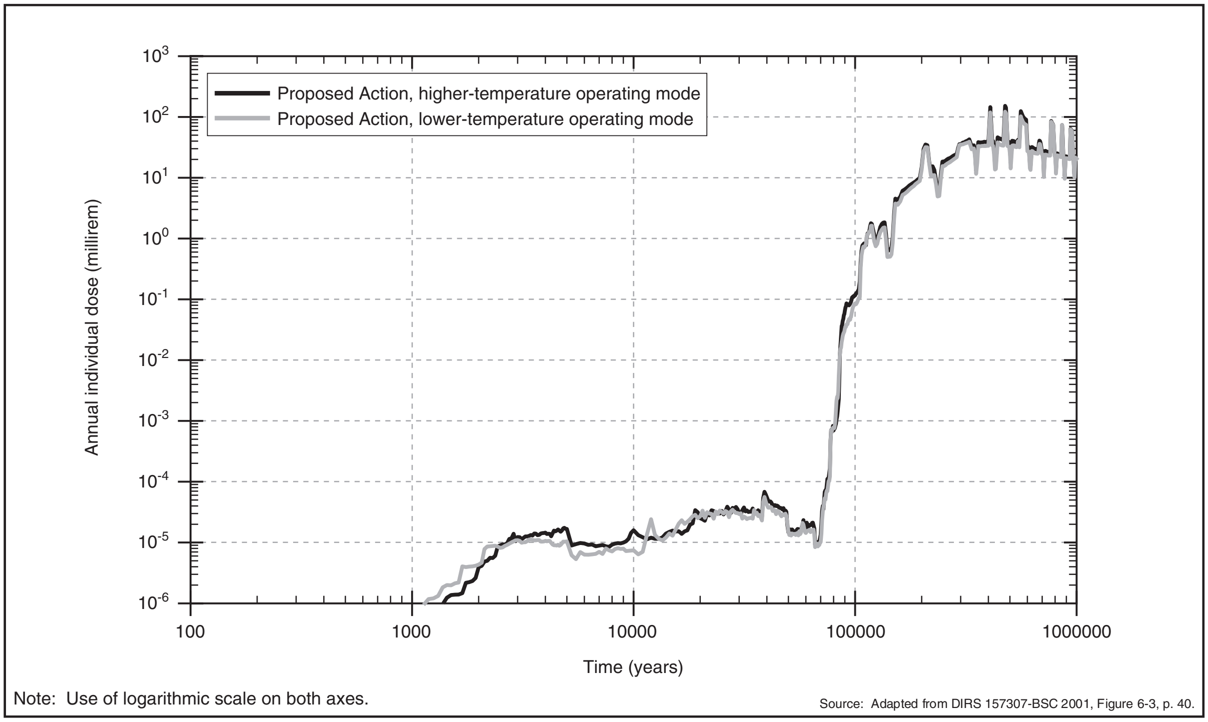


Figure I-10. Comparison plot of the total mean annual individual dose at the RMEI location under the higher-temperature and lower-temperature operating modes for the Proposed Action inventory, nominal scenario.

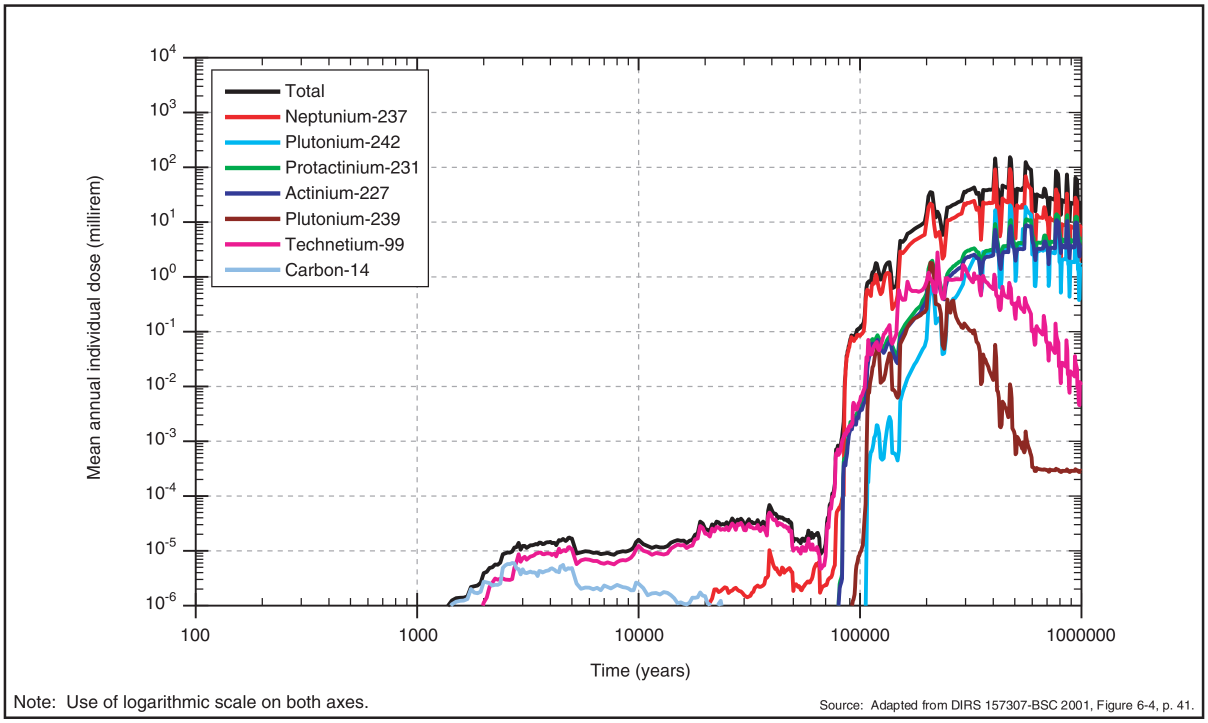


Figure I-11. Total and individual radionuclide mean annual dose to an individual at the RMEI location for the higher-temperature operating mode for the Proposed Action inventory, nominal scenario.

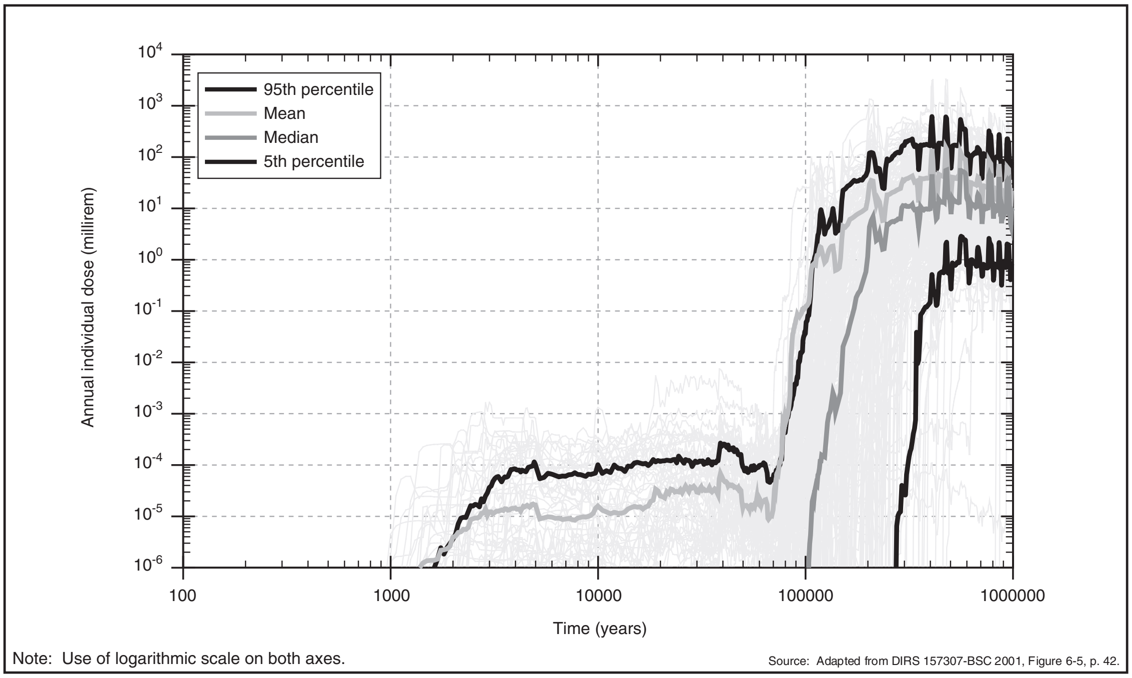


Figure I-12. Total annual individual dose at the RMEI location for 300 probabilistic simulations of the higher-temperature operating mode for the Proposed Action inventory, nominal scenario; the figure also displays the 5th-percentile, median, mean, and 95th-percentile values of these simulations.

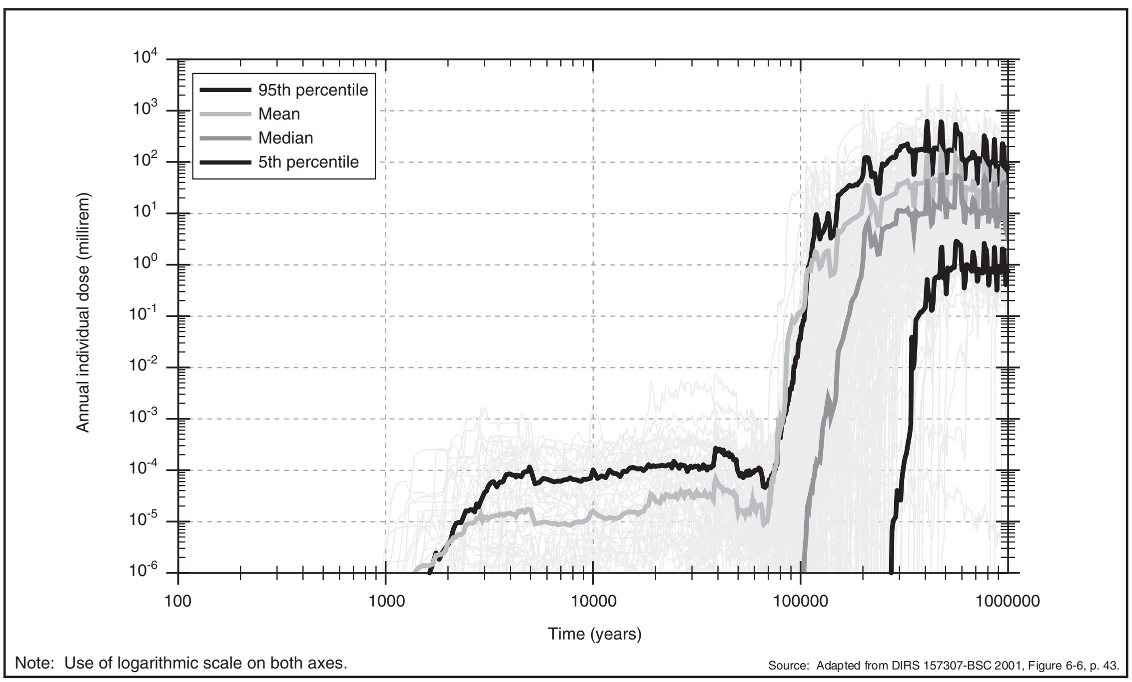


Figure I-13. Total annual individual dose at the RMEI location for 300 probabilistic simulations of the lower-temperature operating mode for the Proposed Action inventory, nominal scenario; the figure also displays the 5th-percentile, median, mean, and 95th-percentile values of these simulations.

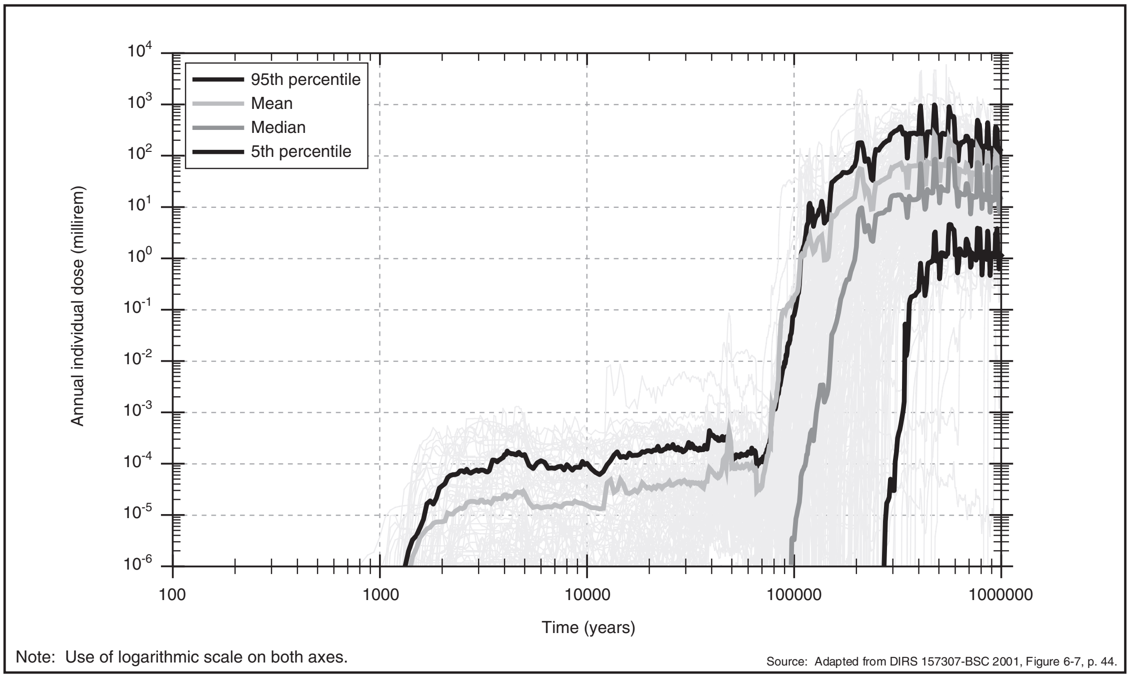


Figure I-14. Total annual individual dose at the RMEI location for 300 probabilistic simulations of the higher-temperature operating mode for the Module 1 inventory, nominal scenario; the figure also displays the 5th-percentile, median, mean, and 95th-percentile values of these simulations.

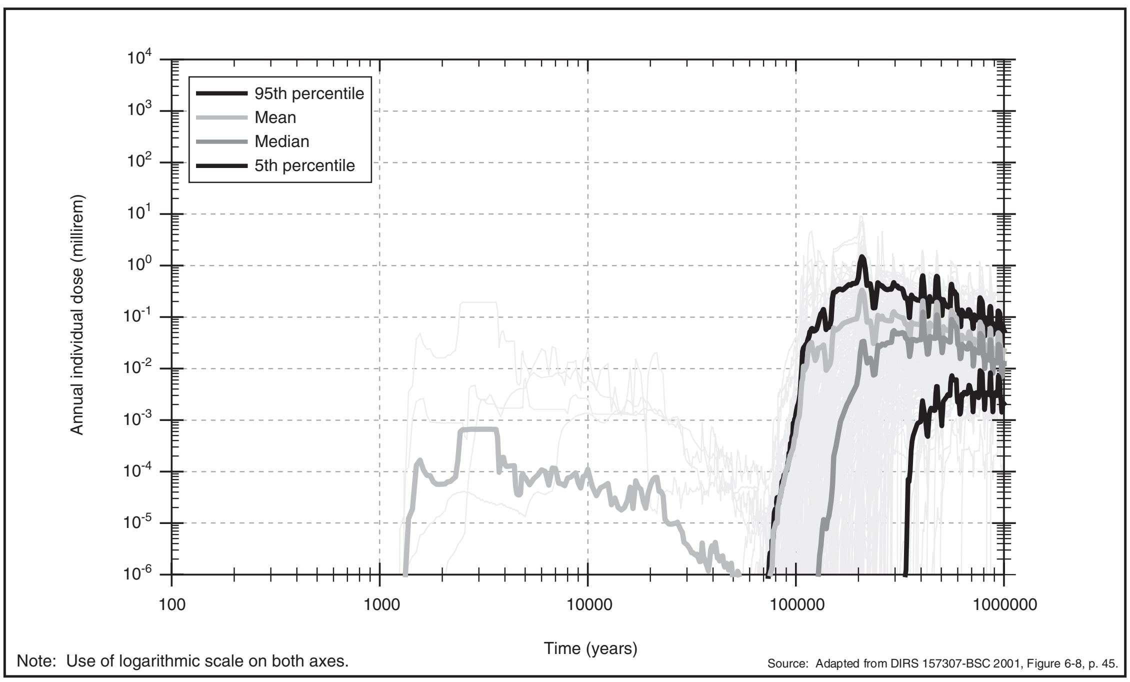
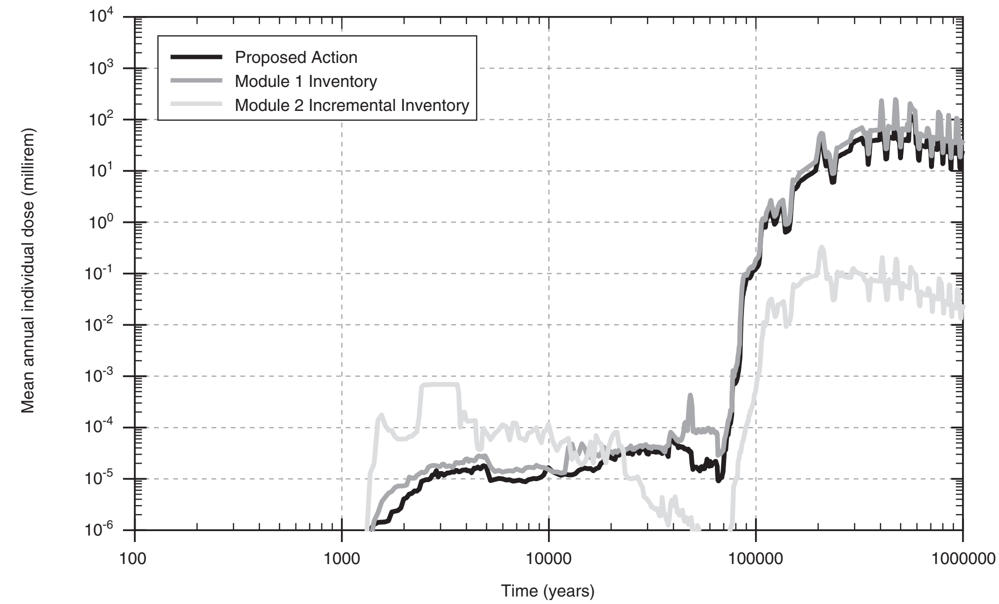


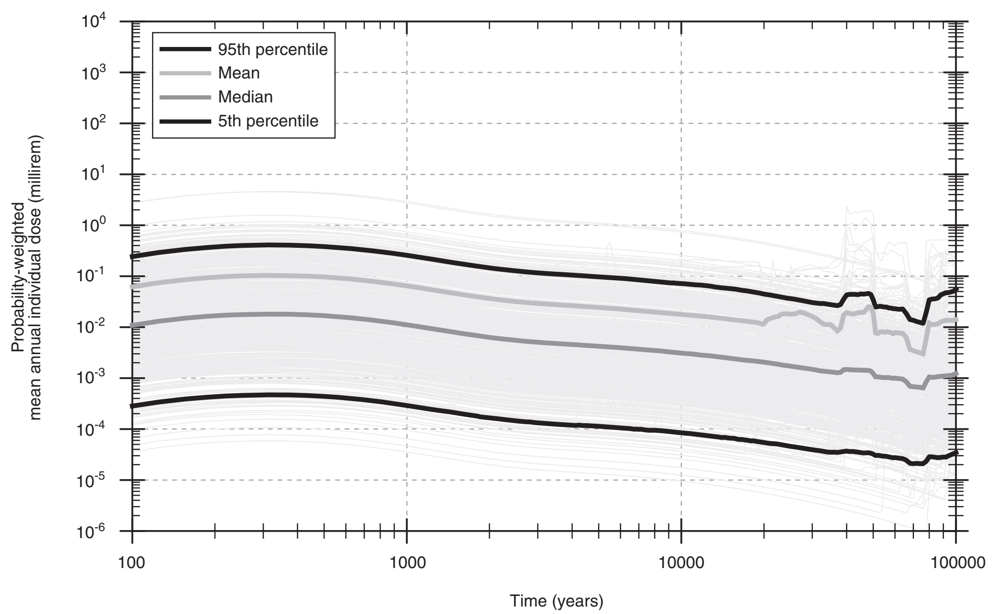
Figure I-15. Total annual individual dose at the RMEI location for 300 probabilistic simulations of the higher-temperature operating mode for the Module 2 incremental inventory, nominal scenario; the figure also displays the 5th-percentile, median, mean, and 95th-percentile values of these simulations.



Note: Use of logarithmic scale on both axes.

Source: Adapted from DIRS 157307-BSC 2001, Figure 6-9, p. 46.

Figure I-16. Comparison plot of the mean total annual individual dose at the RMEI location for the higher-temperature operating mode for the Proposed Action, Module 1, and incremental Module 2 inventories, nominal scenario.



Note: Use of logarithmic scale on both axes.

Source: Adapted from DIRS 157307-BSC 2001, Figure 6-10a, p. 47.

Figure I-17. Total annual individual dose at the RMEI location for 500 out of 5,000 probabilistic simulations of the higher-temperature operating mode for the Proposed Action inventory under the igneous activity scenario; the figure also displays the 5th-percentile, median, mean, and 95th-percentile values of all 5,000 simulations.

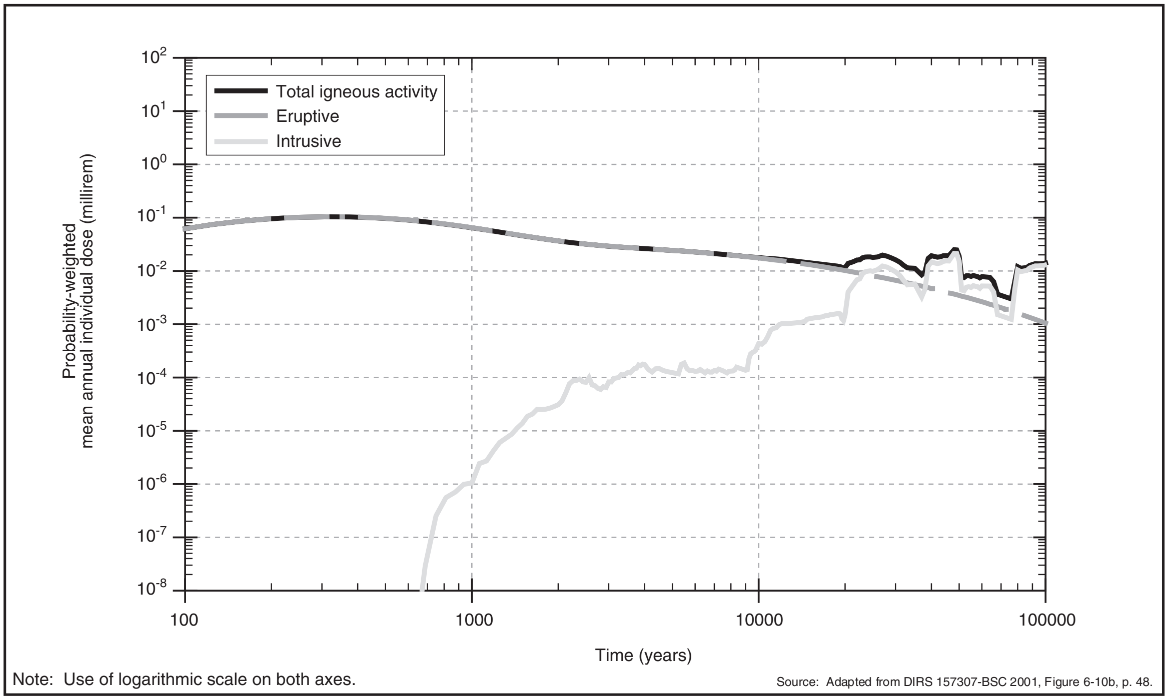


Figure I-18. Total mean individual receptor dose at the RMEI location for the higher-temperature operating mode for the Proposed Action inventory under the igneous activity scenario; the figure displays the mean results for both the eruptive and intrusive events and the sum of these events as "Total Igneous."

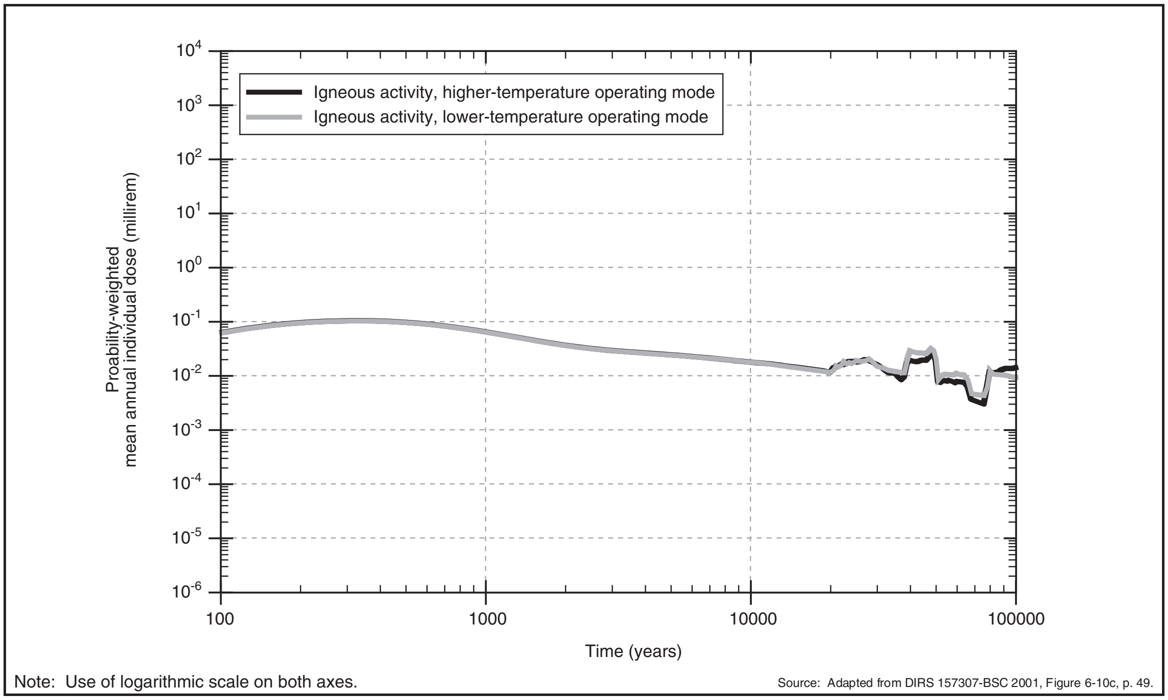


Figure I-19. Total mean annual individual dose at the RMEI location for the higher-temperature and lower-temperature operating modes for the Proposed Action inventory under the igneous activity scenario.

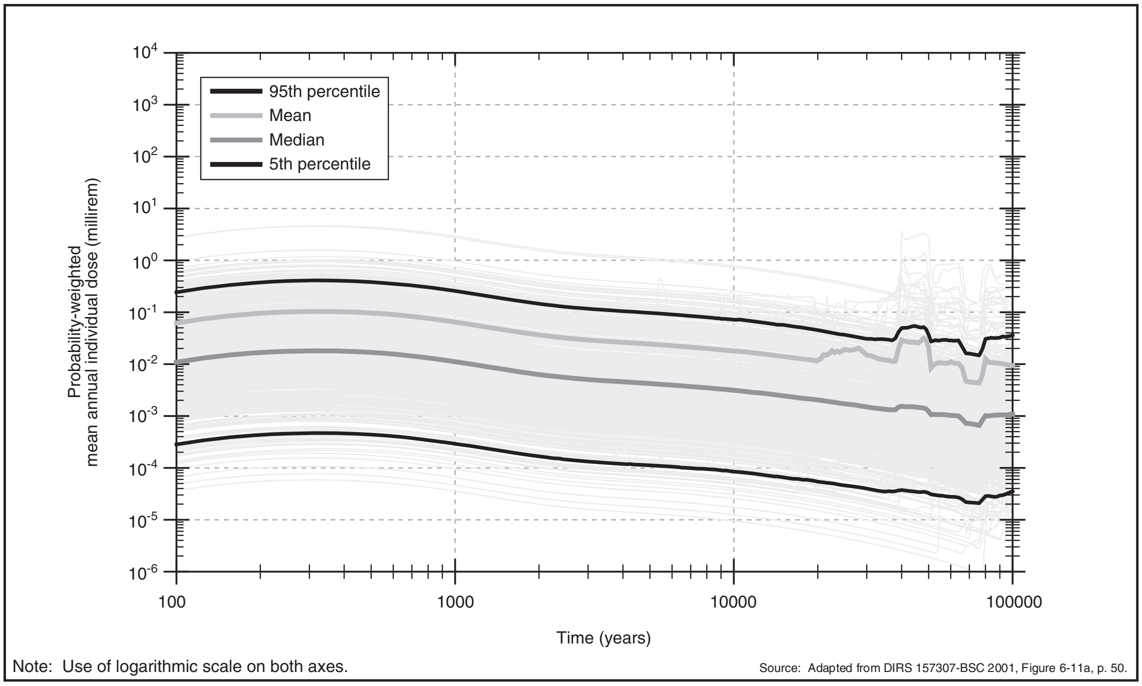


Figure I-20. Total annual individual dose at the RMEI location for 500 out of 5,000 probabilistic simulations of the lower-temperature operating mode for the Proposed Action inventory under the igneous activity scenario; the figure also displays the 5th-percentile, median, mean, and 95th-percentile values of these simulations.

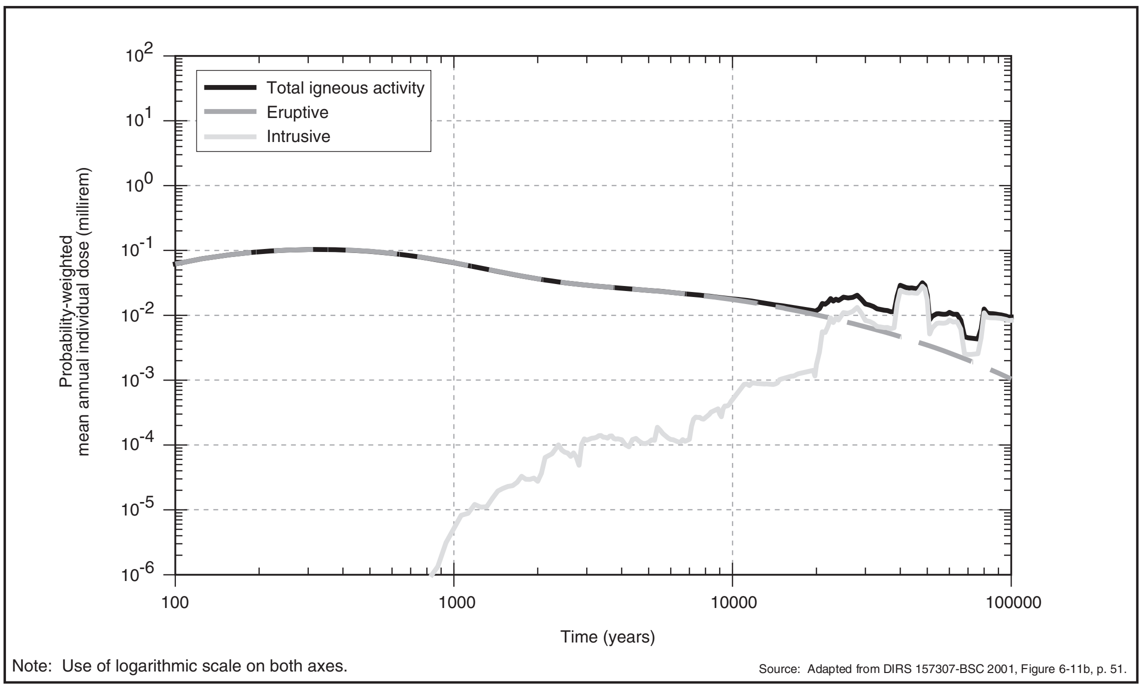
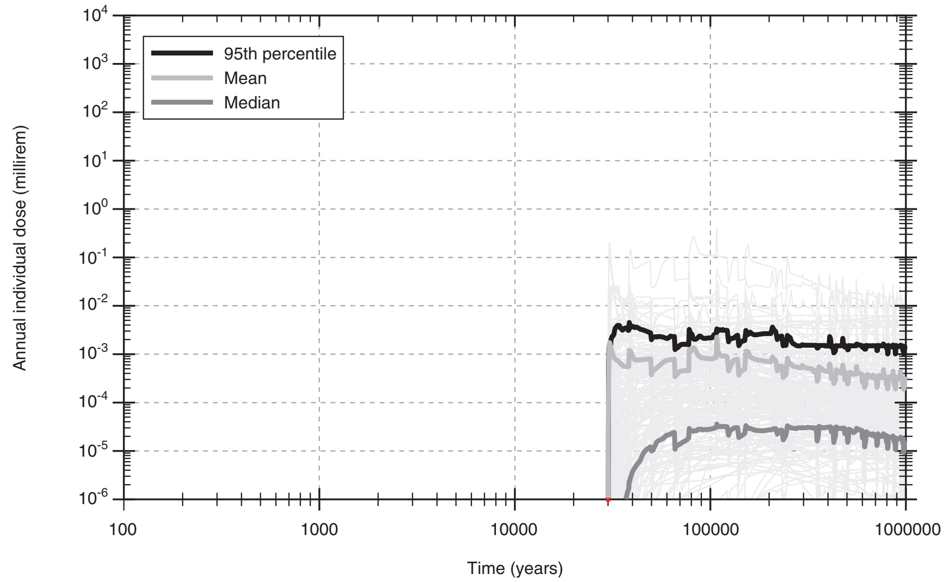


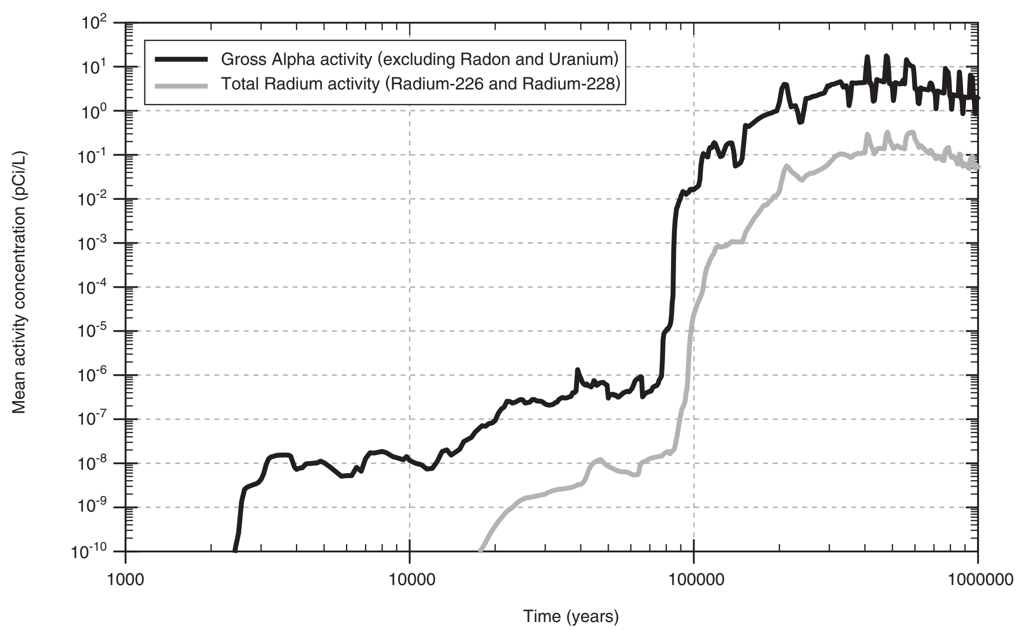
Figure I-21. Total mean annual individual dose at the RMEI location for the lower-temperature operating mode for the Proposed Action inventory under the igneous activity scenario; the figure displays the mean results for both the eruptive and intrusive events and the sum of these events as “Total Igneous.”



Note: Use of logarithmic scale on both axes.

Source: Adapted from DIRS 157307-BSC 2001, Figure 6-12, p. 52.

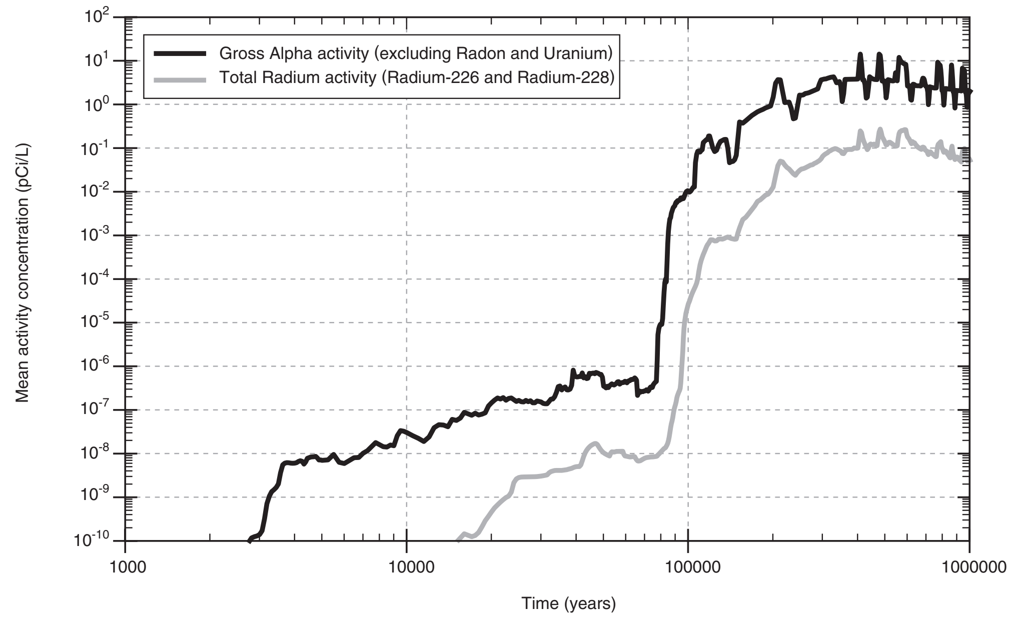
Figure I-22. Total annual individual dose at the RMEI location for 300 probabilistic simulations of the higher-temperature operating mode for the Proposed Action inventory under the human intrusion-at-30,000-years scenario; the figure also displays the median, mean, and 95th-percentile values of these simulations.



Note: Use of logarithmic scale on both axes.

Source: Adapted from DIRS 157307-BSC 2001, Figure 6-17, p. 57.

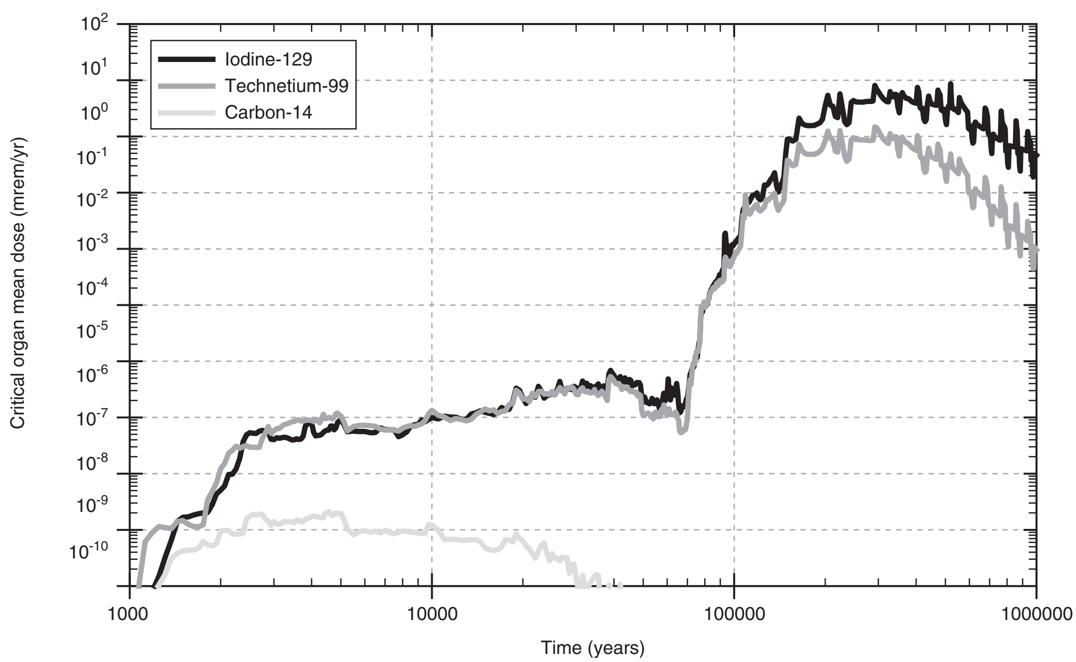
Figure I-23. Mean activity concentrations of gross alpha activity and total radium (radium-226 plus radium-228) at the RMEI location of 300 probabilistic simulations of the higher-temperature operating mode for the Proposed Action inventory for the nominal scenario.



Note: Use of logarithmic scale on both axes.

Source: Adapted from DIRS 157307-BSC 2001, Figure 6-18, p. 58.

Figure I-24. Mean activity concentrations of gross alpha activity and total radium (radium-226 plus radium-228) at the RMEI location of 300 probabilistic simulations of the lower-temperature operating mode for the Proposed Action inventory for the nominal scenario.



Note: Use of logarithmic scale on both axes.

Source: Adapted from DIRS 157307-BSC 2001, Figure 6-19, p. 59.

Figure I-25. Mean dose to critical organs for technetium-99, carbon-14, and iodine-129 at the RMEI location of 300 probabilistic simulations of the higher-temperature operating mode for the Proposed Action inventory for the nominal scenario.

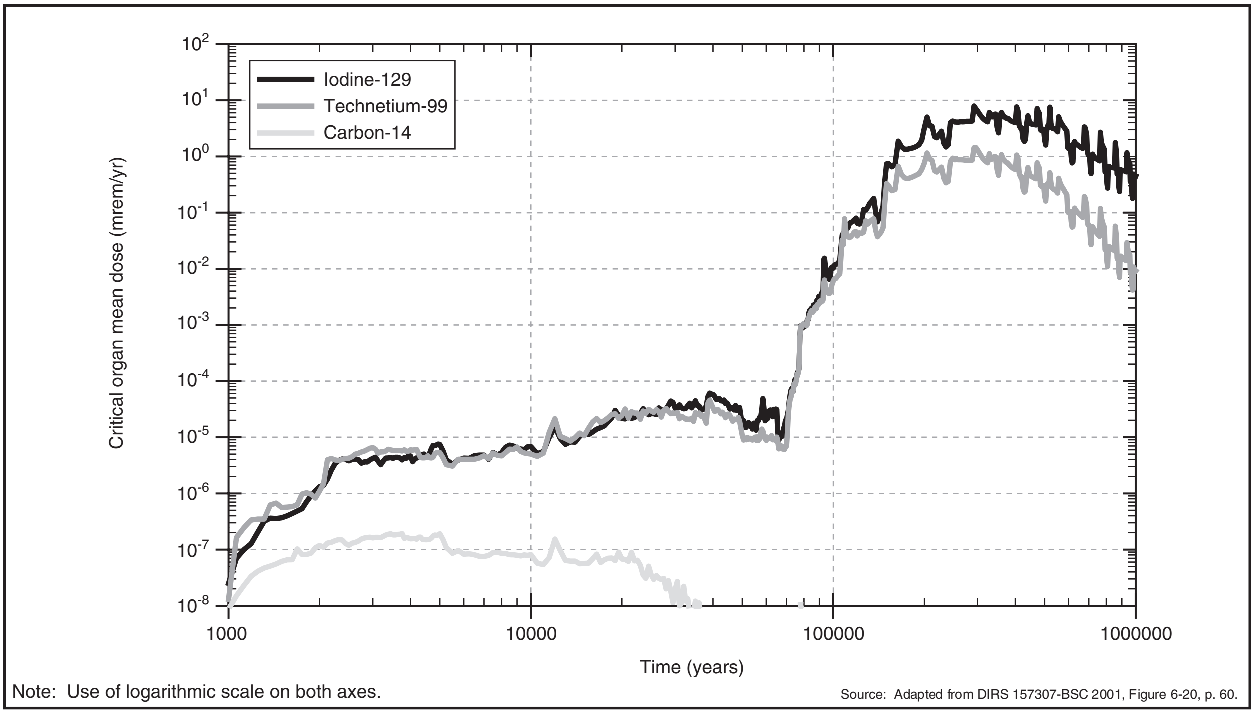


Figure I-26. Mean dose to critical organs for technetium-99, carbon-14, and iodine-129 at the RMEI location of 300 probabilistic simulations of the lower-temperature operating mode for the Proposed Action inventory for the nominal scenario.

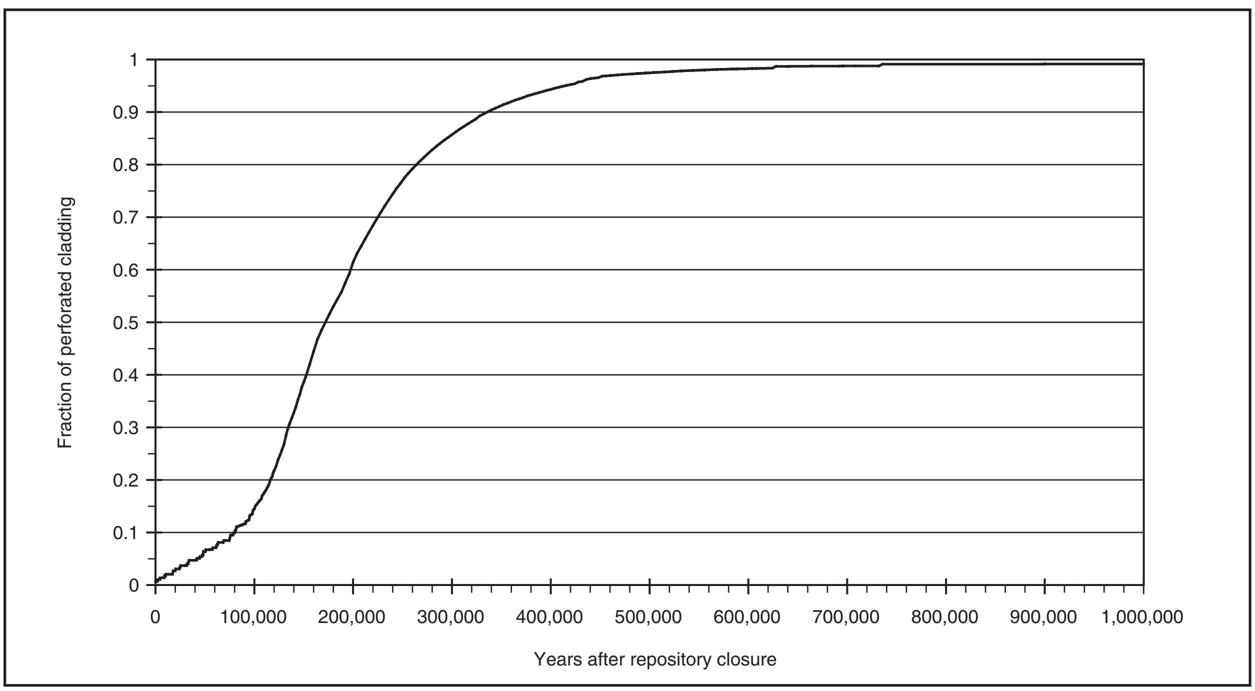


Figure I-27. Fraction of perforated cladding for commercial spent nuclear fuel as a function of time after repository closure.

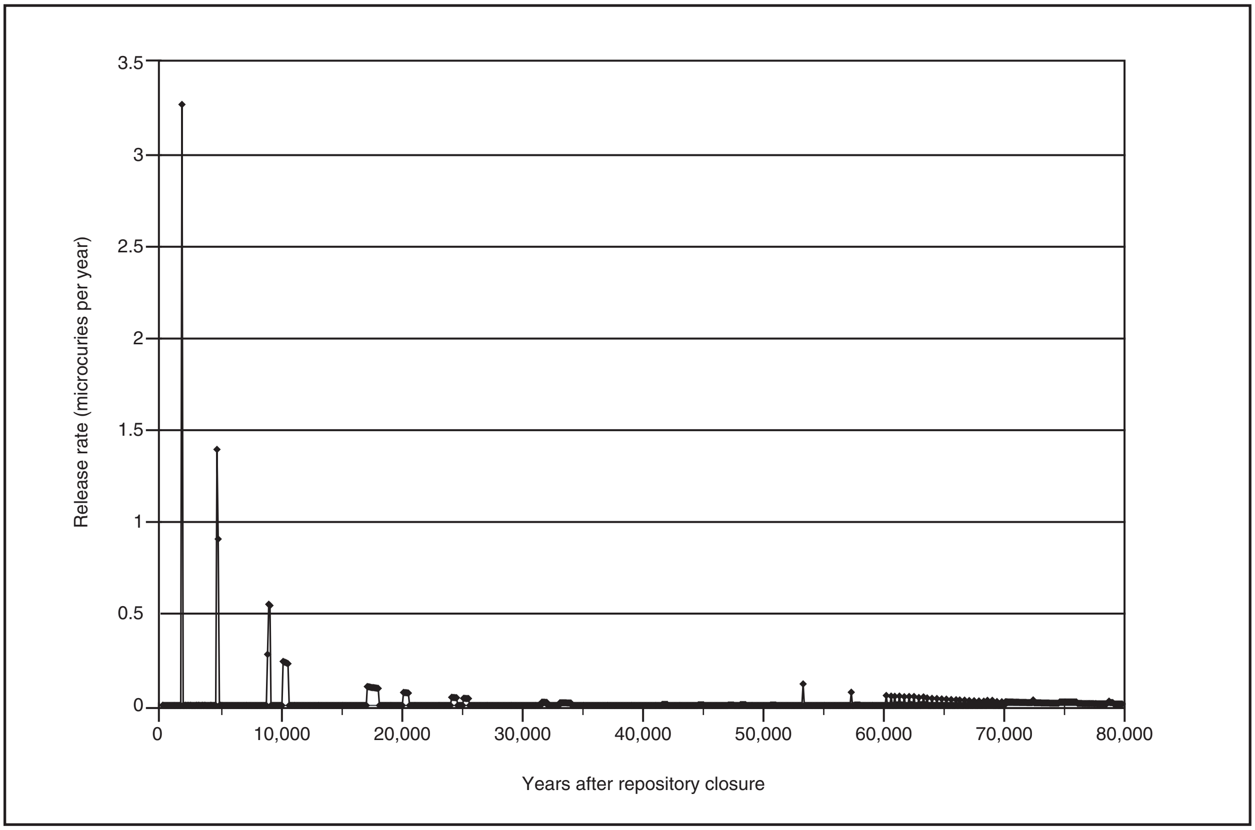


Figure I-28. Release rate of carbon-14 from the repository to the ground surface for 80,000 years following repository closure.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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Appendix J

Transportation

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APPENDIX J. TRANSPORTATION

This appendix provides additional information for readers who wish to gain a better understanding of the methods and analyses the U.S. Department of Energy (DOE or the Department) used to determine the human health impacts of transportation for the Proposed Action and Inventory Modules 1 and 2 discussed in this environmental impact statement (EIS). The materials included in Module 1 are the 70,000 metric tons of heavy metal (MTHM) for the Proposed Action and additional quantities of spent nuclear fuel and high-level radioactive waste that DOE could dispose of in the repository as part of a reasonably foreseeable future action. The materials included in Module 2 include the materials in Module 1 and other highly radioactive materials. Appendix A describes materials included in Modules 1 and 2. This appendix also provides the information DOE used to estimate traffic fatalities that would be associated with the long-term maintenance of storage facilities at 72 commercial sites and 5 DOE sites.

The appendix describes the key data and assumptions DOE used in the analyses and the analysis tools and methods the Department used to estimate impacts of loading operations at 72 commercial and 5 DOE sites; incident-free transportation by highway, rail and barge; intermodal transfer; and transportation accidents. The references listed at the end of this appendix contain additional information.

This appendix presents information on analyses of the impacts of national transportation and on analyses of the impacts that could occur in Nevada. Section J.1 presents information on the analysis of occupational and public health and safety impacts for the transportation of spent nuclear fuel and high-level radioactive waste from the 77 sites to the repository. Section J.2 presents information on the analysis of rail and intermodal transportation alternatives. Section J.3 presents information on the analysis of transportation in Nevada. Section J.4 presents state-specific transportation impacts and maps of analyzed state-specific transportation routes.

J.1 Methods Used To Estimate Potential Impacts of Transportation

This section provides information on the methods and data DOE used to estimate impacts from shipping spent nuclear fuel and high-level radioactive waste from 72 commercial sites and 5 DOE sites throughout the United States to the Yucca Mountain Repository.

MOSTLY LEGAL-WEIGHT TRUCK AND MOSTLY RAIL SCENARIOS

The Department would prefer most shipments to a Yucca Mountain repository be made using rail transportation. It also expects that the mostly rail scenario described in this EIS best represents the mix of rail and truck transportation that would be used. However, it cannot be certain of the actual mix of rail and truck transportation that would occur over the 24 years of the Proposed Action. Consequently, DOE used the mostly legal-weight truck and mostly rail scenarios as a basis for the analysis of potential impacts to ensure the analysis addressed the range of possible transportation impacts. The estimated number of shipments for the mostly legal-weight truck and mostly rail scenarios represents the two extremes in the possible mix of transportation modes, thereby covering the range of potential impacts to human health and safety and to the environment for the transportation modes DOE could use for the Proposed Action.

J.1.1 ANALYSIS APPROACH AND METHODS

Three types of impacts could occur to the public and workers from transportation activities associated with the Proposed Action. These would be a result of the transportation of spent nuclear fuel and high-level radioactive waste and of the personnel, equipment, materials, and supplies needed to construct, operate and monitor, and close the proposed Yucca Mountain Repository. The first type, radiological impacts, would be measured by radiological dose to populations and individuals and the resulting estimated number of latent cancer fatalities that would be caused by radiation from shipments of spent nuclear fuel and high-level radioactive waste from the 77 sites under normal and accident transport conditions. The second and third types would be nonradiological impacts—potential fatalities resulting from vehicle emissions and caused by vehicle accidents. The analysis also estimated impacts due to the characteristics of hazardous cargoes from accidents during the transportation of nonradioactive hazardous materials to support repository construction, operation and monitoring, and closure. For perspective, about 11 fatalities resulting from hazardous material occur each year during the transportation of more than 300 million shipments of hazardous materials in the United States (DIRS 156755-BLS 2001, Table A-8). Therefore, DOE expects that the risks from exposure to hazardous materials that could be released during shipments to and from the repository sites would be very small (see Section J.1.4.2.4). The analysis evaluated the impacts of traffic accidents and vehicle emissions arising from these shipments.

The analysis used a step-wise process to estimate impacts to the public and workers. The process used the best available information from various sources and computer programs and associated data to accomplish the steps. Figures J-1 and J-2 show the steps followed in using data and computer programs. DOE has determined that the computer programs identified in the figure are suitable, and provide results in the appropriate measures, for the analysis of impacts performed for this EIS.

The CALVIN computer program (DIRS 155644-CRWMS M&O 1999, all) was used to estimate the numbers of shipments of spent nuclear fuel from commercial sites. This program used information on spent nuclear fuel stored at each site and an assumed scenario for picking up the spent fuel from each site. The program also used information on the capacity of shipping casks that could be used.

The HIGHWAY computer program (DIRS 104780-Johnson et al. 1993, all) is a routing tool used to select existing highway routes that would satisfy U.S. Department of Transportation route selection regulations and that DOE could use to ship spent nuclear fuel and high-level radioactive waste from the 77 sites to the repository.

The INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all) is a routing tool used to select existing rail routes that railroads would be likely to use to ship spent nuclear fuel and high-level radioactive waste from the 77 sites to the repository.

The RADTRAN 5 computer program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) was used in estimating the radiological doses and dose risks to populations and transportation workers resulting from incident-free transportation and to the general population from accident scenarios. For the analysis of incident-free transportation risks, the code used scenarios for persons who would share transportation routes with shipments—called *onlink populations*, persons who live along the route of travel—*offlink populations,* and persons exposed at stops. For accident risks, the code evaluated the range of possible accident scenarios from high probability and low consequence to low probability and high consequence.

The RISKIND computer program (DIRS 101483-Yuan et al. 1995, all) was used to estimate radiological doses to maximally exposed individuals for incident-free transportation and to populations and maximally exposed individuals for accident scenarios. To estimate incident-free doses to maximally exposed individuals, RISKIND used geometry to calculate the dose rate at specified locations that would arise from a source of radiation. RISKIND was also used to calculate the radiation dose to a population and hypothetical maximally exposed individuals from releases of radioactive materials postulated to occur in maximum reasonably foreseeable accident scenarios.

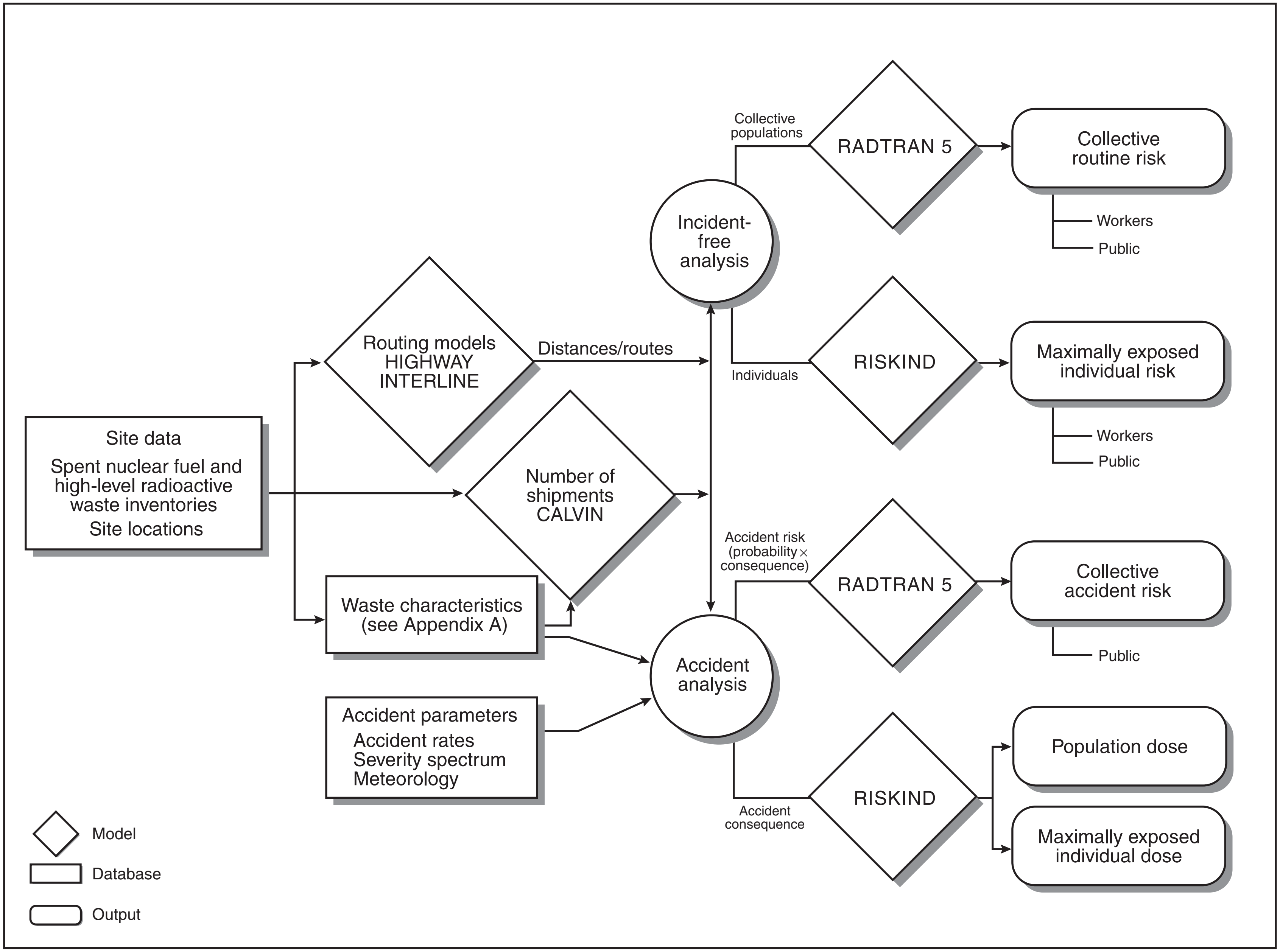

Figure J-1. Methods and approach for analyzing transportation radiological health risk.

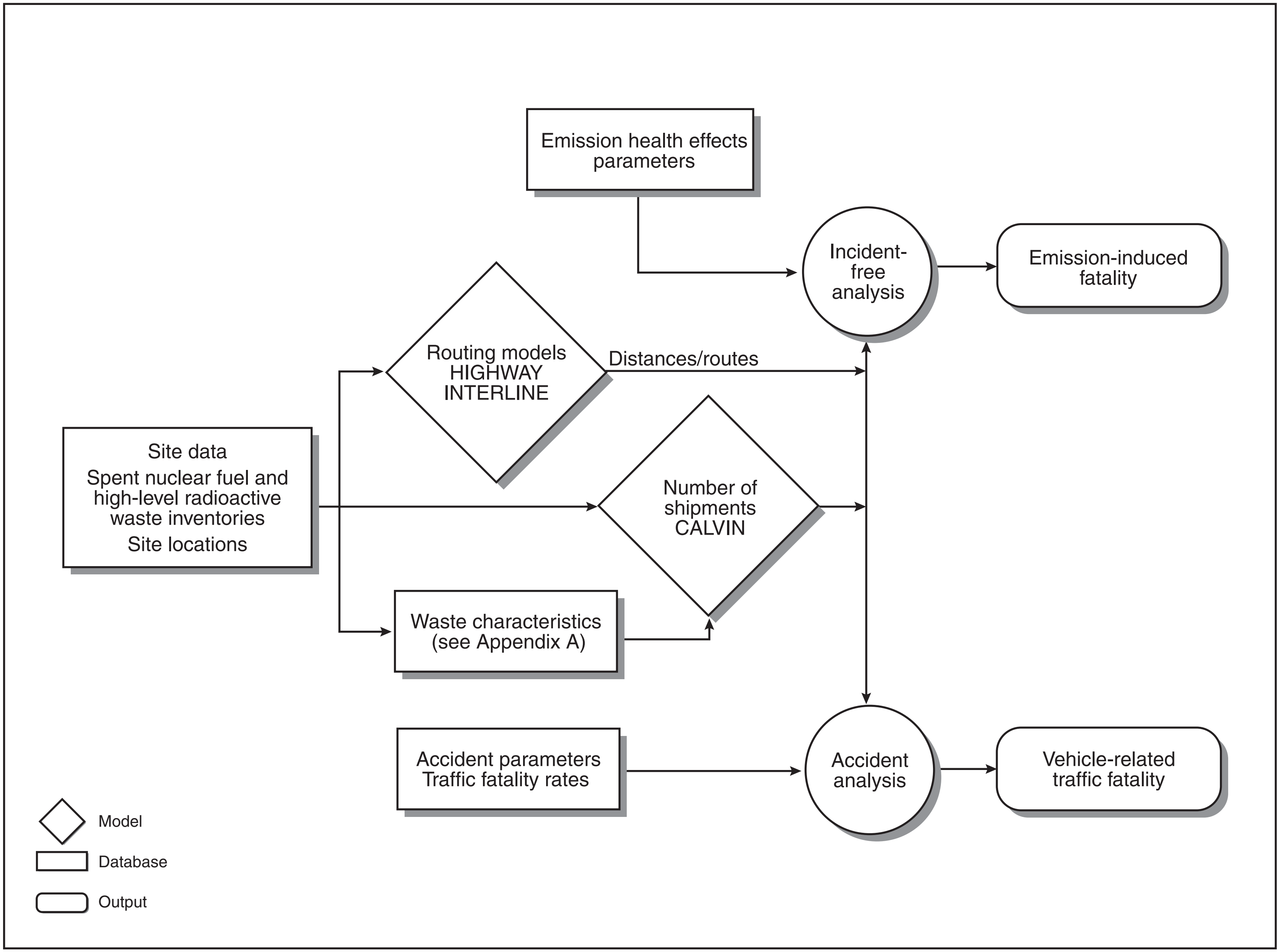

Figure J-2. Methods and approach for analyzing transportation nonradiological health risk.

DOSE RISK

Dose risk is a measure of radiological impacts to populations – public or workers – from the potential for exposure to radioactive materials. Thus, a potential of 1 chance in 1,000 of a population receiving a collective dose of 1 rem (1 person-rem) from an accident would result in a dose risk of 0.001 person-rem (0.001 is the product of 1 person-rem and the quotient of 1 over 1,000). The risk of latent cancer fatalities (a commonly used measure of radiological impact to populations) is obtained by multiplying the dose risk (in person-rem) by a conversion factor of 0.0005 fatal cancer per person-rem for the public. For workers, the conversion factor is 0.0004 fatal cancer per person-rem.

The use of dose risk to measure radiological impacts allows a comparison of alternatives with differing characteristics in terms of radiological consequences that could result and the likelihood that the consequences would actually occur.

The following sections describe these programs in detail.

J.1.1.1 CALVIN

The Civilian Radioactive Waste Management System Analysis and Logistics Visually Interactive (CALVIN) model (DIRS 155644-CRWMS M&O 1999, all) was developed to be a planning tool to estimate the logistic and cost impacts of various operational assumptions for accepting radioactive wastes. CALVIN was used in transportation modeling to determine the number of shipments of commercial spent nuclear fuel from each reactor site. The parameters that the CALVIN model used to determine commercial spent nuclear fuel movement include the shipping cask specifications including heat limits, $k_{infinity}$ (measure of criticality) limits for the contents of the casks, capacity (assemblies or canisters/cask), burnup/enrichment curves, and cooling time for the fuel being shipped.

The source data used by CALVIN for commercial spent nuclear fuel projections include the RW-859 historic data collected by the Energy Information Administration, and the corresponding projection produced based on current industry trends for commercial fuel (see Appendix A). This EIS used CALVIN to estimate commercial spent nuclear fuel shipment numbers based on the cask capacity (see Section J.1.2) and the shipping cask handling capabilities at each site. For the mostly rail national transportation scenario, CALVIN assumed that shipments would use the largest cask a site would be capable of handling. In some cases the analysis, using CALVIN, estimated that the characteristics of the spent nuclear fuel that would be picked up at a site (principally the estimated heat generation rate) would limit the number of fuel assemblies that could be transported to fewer than the full capacity of the cask. In such cases, to provide a realistic estimate of the number of shipments that would be made, CALVIN assumed the cask would contain the smaller number of assemblies. The reduction in capacity was sufficient to accommodate the characteristics of the spent nuclear fuel the program estimated for pickup at the site. In addition, the analysis assumed that sites without sufficient crane capacity to handle a rail cask while operational would be upgraded after reactor shutdown such that the sites could handle rail casks.

J.1.1.2 HIGHWAY

The HIGHWAY computer program (DIRS 104780-Johnson et al. 1993, all) was used to select highway routes for the analysis of impacts presented in this EIS. Using data for actual highways and rules that apply to carriers of Highway Route-Controlled Quantities of Radioactive Materials (49 CFR 397.101), HIGHWAY selected highway routes for legal-weight truck shipments from each commercial and DOE site to the Yucca Mountain site. In addition, DOE used this program to estimate the populations within 800 meters (0.5 mile) of the routes it selected. These population densities were used in calculating incident-free radiological risks to the public along the routes.

One of the features of the HIGHWAY model is its ability to estimate routes for the transport of Highway Route-Controlled Quantities of Radioactive Materials. The U.S. Department of Transportation has established a set of routing regulations for the transport of these materials (49 CFR 397.101). Routes following these regulations are frequently called HM-164 routes. The regulations require the transportation of these shipments on preferred highways, which include:

- Interstate highways
- An Interstate System bypass or beltway around a city
- State-designated preferred routes

State routing agencies can designate preferred routes as an alternative to, or in addition to, one or more Interstate highways. In making this determination, the state must consider the safety of the alternative preferred route in relation to the Interstate route it is replacing, and must register all such designated preferred routes with the U.S. Department of Transportation.

Frequently, the origins and destinations of Highway Route-Controlled Quantities of Radioactive Materials are not near Interstate highways. In general, the U.S. Department of Transportation routing regulations require the use of the shortest route between the pickup location to the nearest preferred route entry location and the shortest route to the destination from the nearest preferred route exit location. In general, HM-164 routes tend to be somewhat longer than other routes; however, the increased safety associated with Interstate highway travel is the primary purpose of the routing regulations.

Because many factors can influence the time in transit over a preferred route, a carrier of Highway Route-Controlled Quantities of Radioactive Materials must select a route for each shipment. Seasonal weather conditions, highway repair or construction, highways that are closed because of natural events (for example, a landslide in North Carolina closed Interstate 40 near the border with Tennessee from June until November 1997), and other events (for example, the 1996 Olympic Games in Atlanta, Georgia) are all factors that must be considered in selecting preferred route segments to reduce time in transit. For this analysis, the highway routes were selected by the HIGHWAY program using an assumption of normal travel and without consideration for factors such as seasons of the year or road construction delays. Although these shipments could use other routes, DOE considers the impacts determined in the analyses to be representative of other possible routings that would also comply with U.S. Department of Transportation regulations. Specific route mileages for truck transportation are presented in Section J.1.2.2.1.

In selecting existing routes for use in the analysis, the HIGHWAY program determined the length of travel in each type of population zone—rural, suburban, and urban. The program characterized rural, suburban, and urban population areas according to the following breakdown: rural population densities range from 0 to 54 persons per square kilometer (0 to 140 persons per square mile); the suburban range is 55 to 1,300 persons per square kilometer (140 to 3,300 persons per square mile); and urban is all population densities greater than 1,300 persons per square kilometer (3,300 persons per square mile). The population densities along a route used by the HIGHWAY program are derived from 1990 data from the Bureau of the Census. In addition, the analysis used results of the 2000 Census for state populations as well as population forecasts published by the Bureau of the Census in estimating radiological impacts to populations that would live along transportation routes (see Sections J.1.3.2.1 and J.1.4.2.1).

J.1.1.3 INTERLINE

Shipments of radioactive materials by rail are not subject to route restrictions imposed by regulations. For general freight rail service, DOE anticipates that railroads would route shipments of spent nuclear fuel and high-level radioactive waste to provide expeditious travel and the minimum practical number of interchanges between railroads. The selection of a route determines the potentially exposed population along the route as well as the expected frequency of transportation-related accidents. The analysis used the INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all) to project the railroad routes that DOE would use to ship spent nuclear fuel and high-level radioactive waste from the sites to the Yucca Mountain site. Specific routes were projected for each originating generator with the exception of six that do not have capability to handle or load a rail transportation cask (see Section J.1.2.1.1). INTERLINE computes rail routes based on rules that simulate historic routing practices of U.S. railroads. The INTERLINE database consists of 94 separate subnetworks and represents various competing rail companies in the United States. The database, which was originally based on data from the Federal Railroad Administration and reflected the U.S. railroad system in 1974, has been expanded and modified extensively over the past two decades. The program is updated periodically to reflect current track conditions and has been benchmarked against reported mileages and observations of commercial rail firms. The program also provides an estimate of the population within 800 meters (0.5 mile) of the routes it selected. This population estimate was used to calculate incident-free radiological risk to the public along the routes selected for analysis.

In general, rail routes are calculated by minimizing the value of a factor called *impedance* between the origin and the destination. The impedance is determined by considering trip distance along a route, the mainline classification of the rail lines that would be used, and the number of interchanges that would occur between different railroad companies involved. In general, impedance determined by the INTERLINE program:

- Decreases as the distance traveled decreases
- Is reduced by use of mainline track that has the highest traffic volume (see below)
- Is reduced for shipments that involve the fewest number of railroad companies

Thus, routes that are the most direct, that use high-traffic volume mainline track, and that involve only one railroad company would have the lowest impedance. The most important of these characteristics from a routing standpoint is the *mainline classification*, which is the measure of traffic volume on a particular link. The mainline classifications used in the INTERLINE routing model are as follows:

- A – mainline – more than 20 million gross ton miles per year
- B – mainline – between 5 and 20 million gross ton miles per year
- A – branch line – between 1 and 5 million gross ton miles per year
- B – branch line – less than 1 million gross ton miles per year

The INTERLINE routing algorithm is designed to route a shipment preferentially on the rail lines having the highest traffic volume. Frequently traveled routes are preferred because they are generally well maintained because the railroad depends on these lines for a major portion of its revenue. In addition, routing along the high-traffic lines usually replicates railroad operational practices.

The population densities along a route were derived from 1990 data from the Bureau of the Census, as described above for the HIGHWAY computer program. In addition, the analysis used the results of the 2000 Census for state populations as well as population forecasts published by the Bureau of the Census to estimate radiological impacts to populations that would live along transportation routes (see Sections J.1.3.2.1 and J.1.4.2.1).

DOE anticipates that routing of rail shipments in dedicated (special) train service, if used, would be similar to routing of general freight shipments for the same origin and destination pairs. However, because cask cars would not be switched between trains at classification yards, dedicated train service would be likely to result in less time in transit.

J.1.1.4 RADTRAN 5

DOE used the RADTRAN 5 computer program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) in conjunction with a Microsoft Access database for the routine and accident cargo-related risk assessment to estimate radiological impacts to collective populations. The Department used RADTRAN 5 to generate risk factors such as transportation impacts per kilometer of travel. The database was used to manage the large amount of data and results for the analysis. Sandia National Laboratories developed RADTRAN 5 to calculate population risks associated with the transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge. The RADTRAN codes, which have been reviewed and updated periodically, have been used extensively by DOE for transportation risk assessment since the late 1970s. In 1995, DIRS 101845-Maheras and Pippen (1995, p. iii) conducted an analysis "to validate the estimates made by" selection of computer codes used to estimate radiation doses from the transportation of radioactive materials. The RADTRAN 4 computer code was included in the analysis. The analysis demonstrated that the RADTRAN 4 code, an earlier version of RADTRAN 5 yielded acceptable results. In the context of this analysis, "acceptable results" means that the differences between the estimates generated by the RADTRAN 4 code and hand calculations were small [that is, less than 5 percent (DIRS 101845-Maheras and Pippen 1995, p. 3-1)]. DIRS 153967-Steinman and Kearfott (2000, all) compared RADTRAN 5 results to measured radiation doses from moving sources, and found that RADTRAN 5 overpredicts the measured radiation dose to the receptor.

The RADTRAN 5/database calculations for routine (or incident-free) dose are based on expressing the dose rate as a function of distance from a point source. Associated with the calculation of routine doses for each exposed population group are parameters such as the radiation field strength, the source-receptor distance, the duration of the exposure, vehicle speed, stopping time, traffic density, and route characteristics such as population density and route segment length. The radiation dose to the exposed population decreases as the source-receptor distance and the vehicle speed increase. The radiation dose to the exposed population increases as the other parameters mentioned above increase. In calculating population doses from incident-free transportation, RADTRAN 5 and the database used population density data provided by the HIGHWAY and INTERLINE computer programs. These data are based on the 1990 Census. The results of the RADTRAN 5/database analyses were escalated to account for population growth to 2035.

In addition to routine doses, the RADTRAN 5/database combination was used to estimate dose risk from a spectrum of accident scenarios. This spectrum encompasses the range of possible accidents, including low-probability accident scenarios that have high consequences, and high-probability accident scenarios that have low consequences (fender benders). The RADTRAN 5/database calculation of collective accident risks for populations along routes employed models that quantified the range of potential accident severities and the responses of the shipping casks to those scenarios. The spectrum of accident severity was divided into categories. Each category of severity has a conditional probability of occurrence; that is, the probability that an accident will be of a particular severity if it occurs. A release fraction, which is the fraction of the material in a shipping cask that could be released in an accident, is assigned to each accident scenario severity category on the basis of the physical and chemical form of the material being transported. The analysis also considered accidents that would lose lead radiation shielding but with no release of radioactive material. The model also considers the mode of transportation, the state-specific accident rates, and population densities for rural, suburban, and urban population zones through which shipments would pass to estimate accident risks for this analysis. The

RADTRAN 5/database calculation used actual population densities within 800 meters (0.5 mile) of the transportation routes based on 1990 Census data to estimate populations within 80 kilometers (50 miles).

For accident scenarios involving releases of radioactive material, RADTRAN 5 assumes that the material is dispersed in the environment (as described by a Gaussian dispersion model). The dispersion analysis assumed that meteorological conditions are national averages for wind speed and atmospheric stability. For the risk assessment, the analysis used these meteorological conditions and assumed an instantaneous ground-level release and a small-diameter source cloud (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, Section 4.1.1). The calculation of the collective population dose following the release and the dispersal of radioactive material includes the following exposure pathways:

- External exposure to the passing radioactive cloud
- External exposure to contaminated ground
- Internal exposure from inhalation of airborne contaminants
- Internal exposure from ingestion of contaminated food

For the ingestion pathway, the analysis used the ground deposition calculated using RADTRAN 5 and state-specific food transfer factors, which relate the amount of radioactive material ingested to the amount deposited on the ground, as input to the database. Radiation doses from the ingestion or inhalation of radionuclides were calculated by using standard dose conversion factors from Federal Guidance Reports No. 11 and 12 (DIRS 104800-CRWMS M&O 1999, p. 36).

POTENTIAL HUMAN HEALTH IMPACTS OF TRANSPORTATION ACCIDENTS THAT COULD CONTAMINATE SURFACE-WATER AND GROUNDWATER RESOURCES

The EIS does not specifically analyze a transportation accident involving contamination of surface water or groundwater. Analyses performed in previous EISs (see Chapter 1, Section 1.5.3 and Table 1-1) have consistently shown that the airborne pathway has the greatest potential for exposing large numbers of people to radioactive material in the event of a release of such material during a severe transportation accident. A paper by R.M. Ostmeyer analyzed the potential importance of water pathway contamination for spent nuclear fuel transportation accident risk using a worst-case water contamination scenario. The analysis showed that the impacts of the water contamination scenario were about 1/50th of the impacts of a comparable accident in an urban area (DIRS 104784-Ostmeyer 1986, all).

J.1.1.5 RISKIND

The RISKIND computer program (DIRS 101483-Yuan et al. 1995, all) was used as a complement to the RADTRAN 5 calculations to estimate scenario-specific doses to maximally exposed individuals for both routine operations and accident conditions and to estimate population impacts for the assessment of accident scenario consequences. The RISKIND code was originally developed for the DOE Office of Civilian Radioactive Waste Management specifically to analyze radiological consequences to individuals and population subgroups from the transportation of spent nuclear fuel and is used now to analyze the transport of other radioactive materials, as well as spent nuclear fuel.

The RISKIND external dose model considers direct external exposure and exposure from radiation scattered from the ground and air. RISKIND was used to calculate the dose as a function of distance from a shipment on the basis of the dimensions of the shipment (millirem per hour for stationary exposures and millirem per event for moving shipments). The code approximates the shipment as a cylindrical volume source, and the calculated dose includes contributions from secondary radiation scatter from buildup (scattering by material contents), cloudshine (scattering by air), and groundshine (scattering by the ground). Credit for potential shielding between the shipment and the receptor was not considered.

The RISKIND code was also used to provide a scenario-specific assessment of radiological consequences of severe transportation-related accidents. Whereas the RADTRAN 5 risk assessment considers the entire range of accident severities and their related probabilities, the RISKIND consequence assessment focuses on accident scenarios that result in the largest releases of radioactive material to the environment that are reasonably foreseeable. The consequence assessment was intended to provide an estimate of the potential impacts posed by a severe, but highly unlikely, transportation-related accident scenario.

The dose to each maximally exposed individual considered was calculated with RISKIND for an exposure scenario defined by a given distance, duration, and frequency of exposure specific to that receptor. The distances and durations were similar to those given in previous transportation risk assessments. The scenarios were not meant to be exhaustive but were selected to provide a range of potential exposure situations.

J.1.2 NUMBER AND ROUTING OF SHIPMENTS

This section discusses the number of shipments and routing information used to analyze potential impacts that would result from preparation for and conduct of transportation operations to ship spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. Table J-1 summarizes the estimated numbers of shipments for the various inventory and national shipment scenario combinations.

J.1.2.1 Number of Shipments

DOE used two analysis scenarios—mostly legal-weight truck and mostly train (rail)—as bases for estimating the number of shipments of spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites. The number of shipments for the scenarios was used in analyzing transportation impacts for the Proposed Action and Inventory Modules 1 and 2. DOE selected the scenarios because, more than 10 years before the projected start of operations at the repository, it cannot accurately predict the actual mix of rail and legal-weight truck transportation that would occur from the 77 sites to the repository. Therefore, the selected scenarios enable the analysis to bound (or bracket) the ranges of legal-weight truck and rail shipments that could occur.

The analysis estimated the number of shipments from commercial sites where spent nuclear fuel would be loaded and shipped and from DOE sites where spent nuclear fuel, naval spent nuclear fuel, and high-level radioactive waste would be loaded and shipped.

For the mostly legal-weight truck scenario, with one exception, shipments were assumed to use legal-weight trucks. Overweight, overdimensional trucks weighing between about 36,300 and 52,200 kilograms (80,000 and 115,000 pounds) but otherwise similar to legal-weight trucks could be used for some spent nuclear fuel and high-level radioactive waste (for example, spent nuclear fuel from the South Texas reactors). The exception that gives the scenario its name—mostly legal-weight truck—was for shipments of naval spent nuclear fuel. Under this scenario, naval spent nuclear fuel would be shipped by rail, as decided in the *Record of Decision for a Dry Storage Container System for the Management of Naval Spent Nuclear Fuel* (62 *FR* 1095; January 8, 1997).

For the mostly rail scenario, the analysis assumed that all sites would ship by rail, with the exception of those with physical limitations that would make rail shipment impractical. The exception would be for shipments by legal-weight trucks from six commercial sites that do not have the capability to load rail casks. However, the analysis also assumed that these six sites would be upgraded to handle a rail cask after the reactors were shut down and would ship either by direct rail or by heavy-haul truck or barge to

Table J-1. Summary of estimated number of shipments for the various inventory and national transportation analysis scenario combinations.

	Mostly truck		Mostly rail	
	Truck	Rail	Truck	Rail
Proposed Action				
Commercial spent nuclear fuel	41,001	0	1,079	7,218
High-level radioactive waste	8,315	0	0	1,663
DOE spent nuclear fuel	3,470	300	0	765
Greater-Than-Class-C waste	0	0	0	0
Special-Performance-Assessment-Required waste	0	0	0	0
Proposed Action totals	*52,786*	*300*	*1,079*	*9,646*
Module 1[a]				
Commercial spent nuclear fuel	79,684	0	3,122	12,989
High-level radioactive waste	22,280	0	0	4,458
DOE spent nuclear fuel	3,721	300	0	796
Greater-Than-Class-C waste	0	0	0	0
Special-Performance-Assessment-Required waste	0	0	0	0
Module 1 totals	*105,685*	*300*	*3,122*	*18,243*
Module 2[a]				
Commercial spent nuclear fuel	79,684	0	3,122	12,989
High-level radioactive waste	22,280	0	0	4,458
DOE spent nuclear fuel	3,721	300	0	796
Greater-Than-Class-C waste	1,096	0	0	282
Special-Performance-Assessment-Required waste	1,763	55	0	410
Module 2 totals	*108,544*	*355*	*3,122*	*18,935*

a. The number of shipments for Module 1 includes all shipments of spent nuclear fuel and high-level radioactive waste included in the Proposed Action and shipments of additional spent nuclear fuel and high-level radioactive waste as described in Appendix A. The number of shipments for Module 2 includes all the shipments in Module 1 and additional shipments of highly radioactive materials described in Appendix A.

nearby railheads. Of these six sites, two are direct rail sites and four are indirect rail sites. Of the four indirect rail sites, three are adjacent to navigable waterways and could ship by barge. In addition, under this scenario, the analysis assumed that 24 commercial sites that do not have direct rail service but that could handle large casks would ship by barge or heavy-haul truck to nearby railheads with intermodal capability.

For commercial spent nuclear fuel, the CALVIN code was used to compute the number of shipments. The number of shipments of DOE spent nuclear fuel and high-level radioactive waste was estimated based on the data in Appendix A and information provided by the DOE sites. The numbers of shipments were estimated based on the characteristics of the materials shipped, mode interface capability (for example, the lift capacity of the cask-handling crane) of each shipping facility, and the modal-mix case analyzed. Table J-2 summarizes the basis for the national and Nevada transportation impact analysis.

Detailed descriptions of spent nuclear fuel and high-level radioactive waste that would be shipped to the Yucca Mountain site are presented in Appendix A.

J.1.2.1.1 *Commercial Spent Nuclear Fuel*

For the analysis, the CALVIN model used 31 shipping cask configurations: 9 for legal-weight truck casks (Figure J-3) and 22 for rail casks (Figure J-4). Table J-3 lists the legal-weight truck and rail cask configurations used in the analysis and their capacities. The analysis assumed that all shipments would use one of the 31 configurations. If the characteristics of the spent nuclear fuel projected for shipment

Table J-2. Analysis basis—national and Nevada transportation scenarios.[a,b]

Material	Mostly legal-weight truck scenario national and Nevada	National mostly rail scenario	
		Nevada rail scenario	Nevada heavy-haul truck scenario
Casks			
Commercial SNF	Truck casks – about 1.8 MTHM per cask	Rail casks – 6 to 12 MTHM per cask for shipments from 66 sites	Rail casks – 6 to 12 MTHM per cask for shipments from 66 sites
		Truck casks – about 1.8 MTHM per cask for shipments from 6 sites[c]	Truck casks – about 1.8 MTHM per cask for shipments from 6 sites
DOE HLW and DOE SNF, except naval SNF	Truck casks – 1 SNF or HLW canister per cask	Rail casks – four to nine SNF or HLW canisters per cask	Rail casks – four to nine SNF or HLW canisters per cask
Naval SNF	Disposal canisters in large rail casks for shipment from INEEL	Disposable canisters in large rail casks for shipments from INEEL	Disposable canisters in large rail casks for shipments from INEEL
Transportation modes			
Commercial SNF	Legal-weight trucks	Direct rail from 49 sites served by railroads to repository	Rail from 49 sites served by railroads to intermodal transfer station in Nevada, then heavy-haul trucks to repository
		Heavy-haul trucks from 7 sites to railhead, then rail to repository	Heavy-haul trucks from 7 sites to railheads, then rail to intermodal transfer station in Nevada, then heavy-haul trucks to repository
		Heavy-haul trucks or barges[d] from 17 sites to railhead, then rail to repository	Heavy-haul trucks or barges[d] from 17 sites to railheads, then rail to intermodal transfer station in Nevada, then heavy-haul trucks to repository
		Legal-weight trucks from 6 sites to repository[c]	Legal-weight trucks from 6 sites to repository[c]
DOE HLW and DOE SNF, except naval SNF	Legal-weight trucks	Rail from DOE sites[e] to repository	Rail from DOE sites[e] to intermodal transfer station in Nevada, then heavy-haul trucks to repository
Naval SNF	Rail from INEEL to intermodal transfer station in Nevada, then heavy-haul trucks to repository	Rail from INEEL to repository	Rail from INEEL to intermodal transfer station in Nevada, then heavy-haul trucks to repository

a. Abbreviations: SNF = spent nuclear fuel; MTHM = metric tons of heavy metal; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory.

b. G. E. Morris facility is included with the Dresden reactor facilities in the 72 commercial sites.

c. The analysis assumed that the six legal-weight truck sites would upgrade their crane capacity upon reactor shutdown and would ship all remaining spent nuclear fuel by rail. Of those six sites, four are heavy-haul sites and two are direct rail sites. Three of the heavy-haul sites have barge capability (Pilgrim, St. Lucie 1, and Indian Point).

d. Seventeen of 24 commercial sites not served by a railroad are on or near a navigable waterway. Some of these 17 sites could ship by barge rather than by heavy-haul truck to a nearby railhead. Salem/Hope Creek treated as two sites for heavy-haul or barge analysis.

e. Hanford Site, Savannah River Site, Idaho National Engineering and Environmental Laboratory, West Valley Demonstration Project, and Ft. St. Vrain.

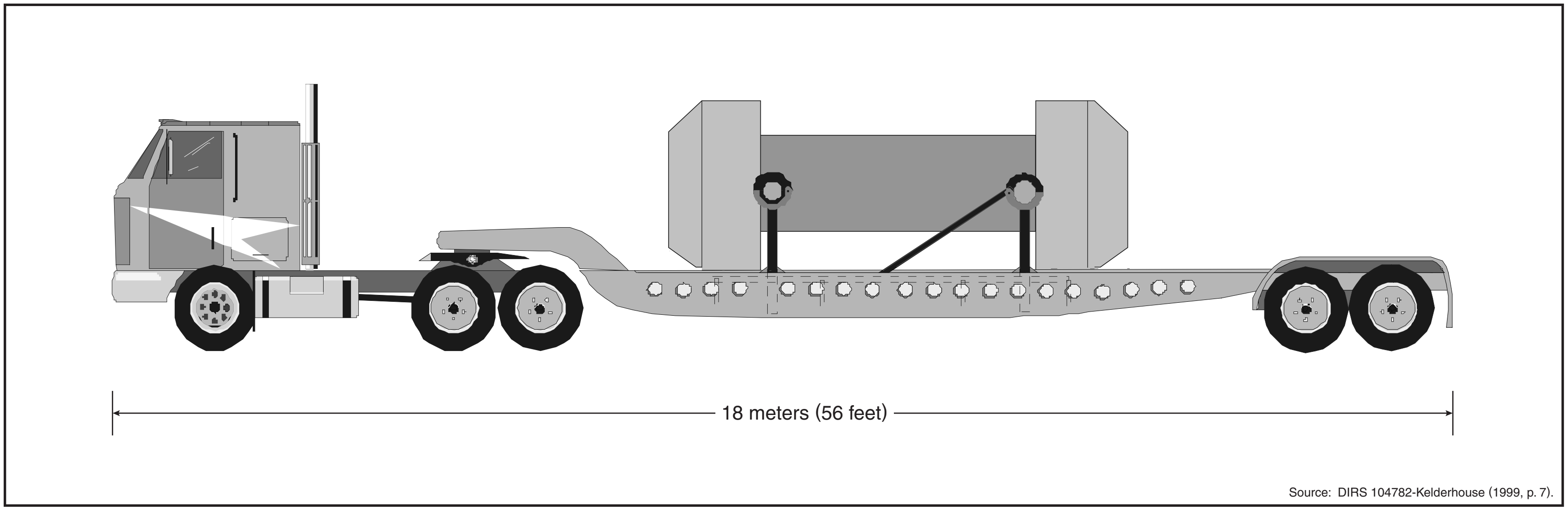

Figure J-3. Artist's conception of a truck cask on a legal-weight tractor-trailer truck.

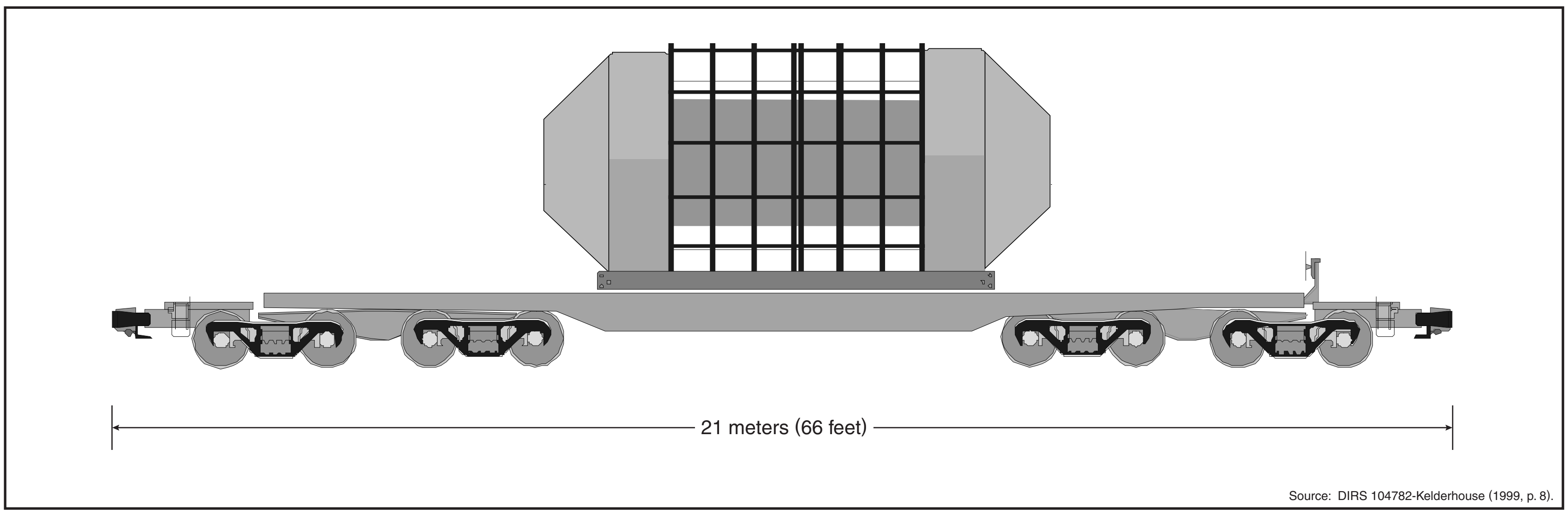

Figure J-4. Artist's conception of a large rail cask on a railcar.

Table J-3. Shipping cask configurations.

Shipping cask	Capacity (number of spent nuclear fuel assemblies)	Description[a,b]
Rail		
B-R-32-SP	32	BWR single-purpose shipping container
B-R-32-SP-HH	32	BWR single-purpose high-heat-capacity shipping container
B-R-44-SP	44	Medium BWR single-purpose shipping container
B-R-68-OV	68	Large BWR overpack shipping container
B-R-68-SP	68	Large BWR single-purpose shipping container
B-R-BP64-OV	64	Plant-unique overpack shipping container
B-R-HI68-OV	68	BWR HISTAR overpack shipping container
B-R-NAC56-OV	56	BWR NAC UMS overpack shipping container
P-R-12-SP	12	Small PWR single-purpose shipping container
P-R-12-SP-HH	12	Small PWR single-purpose high-heat-capacity shipping container
P-R-21-SP	21	Medium PWR single-purpose shipping container
P-R-24-OV	24	Large PWR overpack shipping container
P-R-24-SP	24	Large PWR single-purpose shipping container
P-R-7-SP-HH	7	PWR high heat shipping container
P-R-9-OV-MOX	9	PWR mixed-oxide overpack shipping container
P-R-9-SP-MOX	9	PWR mixed-oxide single-purpose shipping container
P-R-MP24-OV	24	PWR MP-187 (large) overpack shipping container
P-R-NAC26-OV	26	PWR NAC UMS overpack shipping container
P-R-ST17-SP	17	PWR plant-unique single-purpose shipping container
P-R-VSC24-OV	24	PWR Transtor ventilated storage cask overpack shipping container
P-R-WES21-OV	21	PWR WESFLEX overpack shipping container
P-R-YR36-OV	36	PWR plant-unique overpack shipping container
Truck		
B-T-9/9-SP	9	BWR single-purpose shipping container
B-T-9/7-SP	7	Derated BWR single-purpose shipping container
P-T-4/4-SP	4	Primary PWR single-purpose shipping container
P-T-4/3-SP	3	Derated PWR single-purpose shipping container
P-T-4/2-SP	2	Derated PWR single-purpose shipping container
P-T-4/4-SP-ST	4	PWR plant-unique single-purpose shipping container
P-T-4/3-SP-ST	3	PWR Derated plant-unique single-purpose shipping container
P-T-4/4-SP-MOX	4	PWR Mixed-oxide single-purpose shipping container
P-T-4/4-SP-BP	1	PWR plant-unique single-purpose shipping container

a. Source: DIRS 157206-CRWMS M&O (2000, all).
b. BWR = boiling-water reactor; PWR = pressurized-water reactor; SNF = spent nuclear fuel.

exceeded the capabilities of one of the casks, the model reduced the cask's capacity for the affected shipments. The reduction, which is sometimes referred to as cask derating, was needed to satisfy nuclear criticality, shielding, and thermal constraints. For shipments that DOE would make using specific casks, derating would be accomplished by partially filling the assigned casks in compliance with provisions of applicable Nuclear Regulatory Commission certificates of compliance. An example of derating is discussed in Section 5 of the GA-4 legal-weight truck shipping cask design report (DIRS 101831-General Atomics 1993, p. 5.5-1). The analysis addresses transport of two high-burnup or short cooling time pressurized-water reactor assemblies rather than four design basis assemblies.

RAIL SHIPMENTS

This appendix assumes that rail shipments of spent nuclear fuel would use large rail shipping casks, one per railcar. DOE anticipates that as many as five railcars with casks containing spent nuclear fuel or high-level radioactive waste would move together in individual trains with buffer cars and escort cars. For general freight service, a train would include other railcars with other materials. In dedicated (or special) service, trains would move only railcars containing spent nuclear fuel or high-level radioactive waste and the buffer and escort cars.

For the mostly rail scenario, six sites without sufficient crane capacity to lift a rail cask or without other factors such as sufficient floor loading capacity or ceiling height were assumed to ship by legal-weight truck. However, the analysis assumed that these sites would be upgraded to handle rail casks once the reactors were shut down, and all remaining spent nuclear fuel would ship by rail. Of these six sites, two are direct rail and four are indirect rail sites. Of the four with indirect rail access, three have access to a navigable waterway. The 24 sites with sufficient crane capacity but without direct rail access were assumed to ship by heavy-haul truck to the nearest railhead. Of these 24 sites, 17 with access to navigable waterways were analyzed for shipping by barge to a railhead (see Section J.2.4). The number of rail shipments (direct or indirect) was estimated based on each site using the largest cask size feasible based on the load capacity of its cask handling crane. In calculating the number of shipments from the sites, the model used the *Acceptance, Priority Ranking & Annual Capacity Report* (DIRS 104382-DOE 1995, all). Using CALVIN, the number of shipments of legal-weight truck casks (Figure J-3) of commercial spent nuclear fuel estimated for the Proposed Action (63,000 MTHM of commercial spent nuclear fuel) for the mostly legal-weight truck scenario, would be about 15,000 containing boiling-water reactor assemblies and 26,000 containing pressurized-water reactor assemblies. Under Inventory Modules 1 and 2, for which approximately 105,000 MTHM of commercial spent nuclear fuel would be shipped to the repository (see Appendix A), the estimated number of shipments for the mostly legal-weight truck scenario would be 29,000 for boiling-water reactor spent nuclear fuel and 51,000 for pressurized-water reactor spent nuclear fuel. Table J-4 lists the number of shipments of commercial spent nuclear fuel for the mostly legal-weight truck scenario. Specifically, it lists the site, plant, and state where shipments would originate, the total number of shipments from each site, and the type of spent nuclear fuel that would be shipped. A total of 72 commercial sites with 104 plants (or facilities) are listed in the table.

The number of shipments of truck and rail casks (Figure J-4) of commercial spent nuclear fuel estimated for the Proposed Action for the mostly rail scenario would be approximately 2,700 for boiling-water reactor spent nuclear fuel and 5,600 for pressurized-water reactor spent nuclear fuel. Under Modules 1 and 2, the estimated number of shipments for the mostly rail scenario would be approximately 5,400 containing boiling-water reactor spent nuclear fuel and 10,700 containing pressurized-water reactor spent nuclear fuel. Table J-5 lists the number of shipments for the mostly rail scenario. It also lists the site and state where shipments would originate, the total number of shipments from each site, the size of rail cask assumed for each site, and the type of spent nuclear fuel that would be shipped. In addition, it lists the 24 sites not served by a railroad that would ship rail casks by barge or heavy-haul trucks to a nearby railhead and the 6 commercial sites without capability to load a rail cask.

J.1.2.1.2 *DOE Spent Nuclear Fuel and High-Level Radioactive Waste*

To estimate the number of DOE spent nuclear fuel and high-level radioactive waste shipments, the analysis used the number of handling units or number of canisters and the number of canisters per shipment reported by the DOE sites in 1998 (see Appendix A, p. A-34; DIRS 104778-Jensen 1998, all). To determine the number of shipments of DOE spent nuclear fuel and high-level radioactive waste, the analysis assumed one canister would be shipped in a legal-weight truck cask. For rail shipments, the analysis assumed that five 61-centimeter (24-inch)-diameter high-level radioactive waste canisters would be shipped in a rail cask. For rail shipments of DOE spent nuclear fuel, the analysis assumed that rail casks would contain nine approximately 46-centimeter (18-inch) canisters or four approximately 61-centimeter canisters. The number of DOE spent nuclear fuel canisters of each size is presented in Appendix A.

Under the mostly legal-weight truck scenario for the Proposed Action, DOE would transport a total of 11,785 truck shipments of DOE spent nuclear fuel and high-level radioactive waste (one high-level waste canister per shipment) to the repository. In addition, DOE would transport 300 shipments of naval spent nuclear fuel by rail from the Idaho National Engineering and Environmental Laboratory to the repository

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Table J-4. Shipments of commercial spent nuclear fuel, mostly legal-weight truck scenario[a] (page 1 of 2).

Site	Reactor	State	Fuel type	Proposed Action (2010-2033)	Modules 1 and 2 (2010-2048)
Browns Ferry	Browns Ferry 1	AL	B[b]	738	1,550
	Browns Ferry 3	AL	B	324	807
Joseph M. Farley	Joseph M. Farley 1	AL	P[c]	363	779
	Joseph M. Farley 2	AL	P	330	843
Arkansas Nuclear One	Arkansas Nuclear One, Unit 1	AR	P	362	645
	Arkansas Nuclear One, Unit 2	AR	P	432	905
Palo Verde	Palo Verde 1	AZ	P	383	694
	Palo Verde 2	AZ	P	375	691
	Palo Verde 3	AZ	P	360	716
Diablo Canyon	Diablo Canyon 1	CA	P	359	971
	Diablo Canyon 2	CA	P	370	1,130
Humboldt Bay	Humboldt Bay	CA	B	44	44
Rancho Seco	Rancho Seco 1	CA	P	124	124
San Onofre	San Onofre 1	CA	P	52	52
	San Onofre 2	CA	P	408	817
	San Onofre 3	CA	P	393	829
Haddam Neck	Haddam Neck	CT	P	255	255
Millstone	Millstone 1	CT	B	321	321
	Millstone 2	CT	P	361	694
	Millstone 3	CT	P	310	1,008
Crystal River	Crystal River 3	FL	P	277	621
St. Lucie	St. Lucie 1	FL	P	426	849
	St. Lucie 2	FL	P	380	987
Turkey Point	Turkey Point 3	FL	P	291	574
	Turkey Point 4	FL	P	292	570
Edwin I. Hatch	Edwin I. Hatch 1	GA	B	939	1,820
Vogtle	Vogtle 1	GA	P	725	1,379
Duane Arnold	Duane Arnold	IA	B	324	576
Braidwood	Braidwood 1	IL	P	565	1,142
Byron	Byron 1	IL	P	617	1,136
Clinton	Clinton 1	IL	B	363	636
Dresden/Morris	Dresden 1	IL	B	76	76
	Dresden 2	IL	B	459	726
	Dresden 3	IL	B	514	760
	Morris[d]	IL	B	319	319
	Morris[d]	IL	P	88	88
LaSalle	LaSalle 1	IL	B	769	2,080
Quad Cities	Quad Cities 1	IL	B	979	1,567
Zion	Zion 1	IL	P	557	557
Wolf Creek	Wolf Creek 1	KS	P	396	678
River Bend	River Bend 1	LA	B	353	636
Waterford	Waterford 3	LA	P	374	607
Pilgrim	Pilgrim 1	MA	B	322	575
Yankee-Rowe	Yankee-Rowe 1	MA	P	134	134
Calvert Cliffs	Calvert Cliffs 1	MD	P	867	1,612
Maine Yankee	Maine Yankee	ME	P	356	356
Big Rock Point	Big Rock Point	MI	B	110	111
D. C. Cook	D. C. Cook 1	MI	P	832	1,759
Fermi	Fermi 2	MI	B	377	662
Palisades	Palisades	MI	P	409	660
Monticello	Monticello	MN	B	257	435
Prairie Island	Prairie Island 1	MN	P	665	1,109
Callaway	Callaway 1	MO	P	435	701
Grand Gulf	Grand Gulf 1	MS	B	592	1,383
Brunswick	Brunswick 1	NC	P	40	40
	Brunswick 2	NC	P	36	36
	Brunswick 1	NC	B	281	702
	Brunswick 2	NC	B	282	657

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Table J-4. Shipments of commercial spent nuclear fuel, mostly legal-weight truck scenario[a] (page 2 of 2).

Site	Reactor	State	Fuel type	Proposed Action (2010-2033)	Modules 1 and 2 (2010-2048)
Shearon Harris	Shearon Harris 1	NC	P	289	549
	Shearon Harris	NC	B	152	152
McGuire	McGuire 1	NC	P	372	932
	McGuire 2	NC	P	419	1,069
Cooper Station	Cooper Station	NE	B	272	621
Fort Calhoun	Fort Calhoun	NE	P	260	457
Seabrook	Seabrook 1	NH	P	277	590
Oyster Creek	Oyster Creek 1	NJ	B	451	658
Salem/Hope Creek	Salem 1	NJ	P	329	725
	Salem 2	NJ	P	304	826
	Hope Creek	NJ	B	444	796
James A. FitzPatrick/	James A. FitzPatrick	NY	B	413	732
Nine Mile Point	Nine Mile Point 1	NY	B	426	628
	Nine Mile Point 2	NY	B	387	722
Ginna	Ginna	NY	P	320	472
Indian Point	Indian Point 1	NY	P	40	40
	Indian Point 2	NY	P	400	805
	Indian Point 3	NY	P	285	694
Davis-Besse	Davis-Besse 1	OH	P	343	786
Perry	Perry 1	OH	B	293	528
Trojan	Trojan	OR	P	195	195
Beaver Valley	Beaver Valley 1	PA	P	309	649
	Beaver Valley 2	PA	P	248	472
Limerick	Limerick 1	PA	B	740	1,354
Peach Bottom	Peach Bottom 2	PA	B	567	1,023
	Peach Bottom 3	PA	B	575	1,035
Susquehanna	Susquehanna 1	PA	B	1,044	2,482
Three Mile Island	Three Mile Island 1	PA	P	320	654
Catawba	Catawba 1	SC	P	327	555
	Catawba 2	SC	P	310	574
Oconee	Oconee 1	SC	P	970	1,668
	Oconee 3	SC	P	324	666
H. B. Robinson	H. B. Robinson 2	SC	P	249	470
Summer	Summer 1	SC	P	281	713
Sequoyah	Sequoyah	TN	P	644	1,768
Watts Bar	Watts Bar 1	TN	P	158	552
Comanche Peak	Comanche Peak 1	TX	P	665	1,409
South Texas	South Texas 1	TX	P	271	614
	South Texas 2	TX	P	257	590
North Anna	North Anna 1	VA	P	675	1,588
Surry	Surry 1	VA	P	863	1,457
Vermont Yankee	Vermont Yankee 1	VT	B	380	613
Columbia Generating Station	Columbia Generating Station	WA	B	415	1,006
Kewaunee	Kewaunee	WI	P	306	516
LaCrosse	LaCrosse	WI	B	37	37
Point Beach	Point Beach	WI	P	653	1,051
Total BWR[b]				15,229	28,719
Total PWR[c]				25,772	50,965

a. Source: DIRS 157206-CRWMS M&O (2000, all).
b. B = boiling-water reactor (BWR).
c. P = pressurized-water reactor (PWR).
d. Morris is a storage facility located close to the three Dresden reactors.

Table J-5. Shipments of commercial spent nuclear fuel, mostly rail scenario[a] (page 1 of 2).

Site	Reactor	State	Fuel type	Cask	Proposed Action 2010 - 2033	Modules 1 and 2 2010 - 2048
Browns Ferry	Browns Ferry 1	AL	B[b]	Rail	122	247
	Browns Ferry 3	AL	B	Rail	51	120
Joseph M. Farley	Joseph M. Farley 1	AL	P[c]	Rail	57	132
	Joseph M. Farley 2	AL	P	Rail	53	131
Arkansas Nuclear One	Arkansas Nuclear One, Unit 1	AR	P	Rail	57	108
	Arkansas Nuclear One, Unit 2	AR	P	Rail	64	149
Palo Verde	Palo Verde 1	AZ	P	Rail	65	97
	Palo Verde 2	AZ	P	Rail	62	94
	Palo Verde 3	AZ	P	Rail	66	102
Diablo Canyon	Diablo Canyon 1	CA	P	Rail	60	148
	Diablo Canyon 2	CA	P	Rail	61	160
Humboldt Bay	Humboldt Bay	CA	B	Rail	6	6
Rancho Seco	Rancho Seco 1	CA	P	Rail	21	21
San Onofre	San Onofre 1	CA	P	Rail	9	9
	San Onofre 2	CA	P	Rail	65	131
	San Onofre 3	CA	P	Rail	64	137
Haddam Neck	Haddam Neck	CT	P	Rail	40	40
Millstone	Millstone 1	CT	B	Rail	91	91
	Millstone 2	CT	P	Rail	115	199
	Millstone 3	CT	P	Rail	49	138
Crystal River	Crystal River 3	FL	P	Rail	25	17
Crystal River	Crystal River 3	FL	P	Truck	133	437
St Lucie	St. Lucie 1	FL	P	Rail	12	13
St. Lucie	St. Lucie 1	FL	P	Truck	358	751
	St. Lucie 2	FL	P	Rail	61	147
Turkey Point	Turkey Point 3	FL	P	Rail	52	85
	Turkey Point 4	FL	P	Rail	52	86
Edwin I. Hatch	Edwin I. Hatch 1	GA	B	Rail	116	288
Vogtle	Vogtle 1	GA	P	Rail	205	283
Duane Arnold	Duane Arnold	IA	B	Rail	57	129
Braidwood	Braidwood 1	IL	P	Rail	94	162
Byron	Byron 1	IL	P	Rail	101	159
Clinton	Clinton 1	IL	B	Rail	59	87
Dresden/Morris	Dresden 1	IL	B	Rail	11	11
	Dresden 2	IL	B	Rail	83	158
	Dresden 3	IL	B	Rail	89	160
	Morris[d]	IL	B	Rail	43	43
	Morris[d]	IL	P	Rail	15	15
LaSalle	LaSalle 1	IL	B	Rail	101	305
Quad Cities	Quad Cities 1	IL	B	Rail	172	329
Zion	Zion 1	IL	P	Rail	93	93
Wolf Creek	Wolf Creek 1	KS	P	Rail	63	97
River Bend	River Bend 1	LA	B	Rail	57	87
Waterford	Waterford 3	LA	P	Rail	66	93
Pilgrim	Pilgrim 1	MA	B	Rail	24	18
Pilgrim	Pilgrim 1	MA	B	Truck	154	394
Yankee-Rowe	Yankee-Rowe 1	MA	P	Rail	15	15
Calvert Cliffs	Calvert Cliffs 1	MD	P	Rail	169	320
Maine Yankee	Maine Yankee	ME	P	Rail	55	55
Big Rock Point	Big Rock Point	MI	B	Rail	7	7
D. C. Cook	D. C. Cook 1	MI	P	Rail	149	268
Fermi	Fermi 2	MI	B	Rail	61	91
Palisades	Palisades	MI	P	Rail	70	122
Monticello	Monticello	MN	B	Rail	32	19
Monticello	Monticello	MN	B	Truck	8	250
Prairie Island	Prairie Island 1	MN	P	Rail	103	205
Callaway	Callaway 1	MO	P	Rail	71	101
Grand Gulf	Grand Gulf 1	MS	B	Rail	80	215

Table J-5. Shipments of commercial spent nuclear fuel, mostly rail scenario[a] (page 2 of 2).

Site	Reactor	State	Fuel type	Cask	Proposed Action 2010 - 2033	Modules 1 and 2 2010 - 2048
Brunswick	Brunswick 1	NC	P[c]	Rail	14	14
	Brunswick 2	NC	P	Rail	12	12
	Brunswick 1	NC	B[b]	Rail	78	142
	Brunswick 2	NC	B	Rail	78	140
Shearon Harris	Shearon Harris 1	NC	P	Rail	89	146
	Shearon Harris	NC	B	Rail	43	43
McGuire	McGuire 1	NC	P	Rail	83	164
	McGuire 2	NC	P	Rail	89	173
Cooper Station	Cooper Station	NE	B	Rail	42	124
Fort Calhoun	Fort Calhoun	NE	P	Rail	61	120
Seabrook	Seabrook 1	NH	P	Rail	49	80
Oyster Creek	Oyster Creek 1	NJ	B	Rail	64	110
Salem/Hope Creek	Salem 1	NJ	P	Rail	59	101
	Salem 2	NJ	P	Rail	54	108
	Hope Creek	NJ	B	Rail	67	105
James A. FitzPatrick/	FitzPatrick	NY	B	Rail	60	121
Nine Mile Point	Nine Mile Point 1	NY	B	Rail	72	99
	Nine Mile Point 2	NY	B	Rail	65	105
Ginna	Ginna	NY	P	Rail	36	22
Ginna	Ginna	NY	P	Truck	91	297
Indian Point	Indian Point 1	NY	P	Truck	40	40
	Indian Point 2	NY	P	Rail	35	34
	Indian Point 2	NY	P	Truck	150	471
	Indian Point 3	NY	P	Rail	22	19
	Indian Point 3	NY	P	Truck	145	482
Davis-Besse	Davis-Besse 1	OH	P	Rail	64	140
Perry	Perry 1	OH	B	Rail	42	67
Trojan	Trojan	OR	P	Rail	33	33
Beaver Valley	Beaver Valley 1	PA	P	Rail	52	94
	Beaver Valley 2	PA	P	Rail	41	76
Limerick	Limerick 1	PA	B	Rail	148	216
Peach Bottom	Peach Bottom 2	PA	B	Rail	82	157
	Peach Bottom 3	PA	B	Rail	80	157
Susquehanna	Susquehanna 1	PA	B	Rail	201	460
Three Mile Island	Three Mile Island 1	PA	P	Rail	57	97
Catawba	Catawba 1	SC	P	Rail	70	109
	Catawba 2	SC	P	Rail	69	107
Oconee	Oconee 1	SC	P	Rail	208	353
	Oconee 3	SC	P	Rail	64	129
H. B. Robinson	H. B. Robinson 2	SC	P	Rail	82	128
Summer	Summer 1	SC	P	Rail	46	113
Sequoyah	Sequoyah	TN	P	Rail	95	275
Watts Bar	Watts Bar 1	TN	P	Rail	26	74
Comanche Peak	Comanche Peak 1	TX	P	Rail	154	250
South Texas	South Texas 1	TX	P	Rail	58	104
	South Texas 2	TX	P	Rail	57	105
North Anna	North Anna 1	VA	P	Rail	143	289
Surry	Surry 1	VA	P	Rail	197	330
Vermont Yankee	Vermont Yankee 1	VT	B	Rail	73	137
Columbia Generating Station	Columbia Generating Station	WA	B	Rail	77	159
Kewaunee	Kewaunee	WI	P	Rail	51	87
La Crosse	La Crosse	WI	B	Rail	5	5
Point Beach	Point Beach	WI	P	Rail	130	213
Total BWR[b]					2,701	5,402
Total PWR[c]					5,596	10,709

a. Source: DIRS 157206-CRWMS M&O (2000, all).
b. B = boiling-water reactor (BWR).
c. P = pressurized-water reactor (PWR).
d. Morris is a storage facility located close to the three Dresden reactors.

(one naval spent nuclear fuel canister per rail cask). For Modules 1 and 2 under the mostly legal-weight truck scenario, the analysis estimated 26,001 DOE spent nuclear fuel and high-level radioactive waste truck shipments, as well as the 300 naval spent nuclear fuel shipments by rail.

Under the mostly rail scenario for the Proposed Action, the analysis estimated that DOE would transport 2,128 railcar shipments of DOE spent nuclear fuel and high-level radioactive waste (five high-level waste canisters per shipment), as well as the 300 shipments of naval spent nuclear fuel. For Modules 1 and 2 under this scenario, DOE would transport 4,954 railcar shipments of DOE spent nuclear fuel and high-level radioactive waste, as well as the 300 shipments of naval spent nuclear fuel. Table J-6 lists the estimated number of shipments of DOE and naval spent nuclear fuel from each of the sites for both the Proposed Action and Modules 1 and 2. Table J-7 lists the number of shipments of high-level radioactive waste for the Proposed Action and for Modules 1 and 2.

Table J-6. DOE and naval spent nuclear fuel shipments by site.

	Proposed Action		Module 1 or 2	
Site	Mostly truck	Mostly rail	Mostly truck	Mostly rail
INEEL[a]	1,388[b]	433	1,467[c]	442
Savannah River Site	1,316	149	1,411	159
Hanford	754	147	809	157
Fort St. Vrain	312	36	334	38
Totals	***3,770***	***765***	***4,021***	***796***

a. INEEL = Idaho National Engineering and Environmental Laboratory.
b. Includes 1,088 truck shipments of DOE spent nuclear fuel and 300 railcar shipments of naval spent nuclear fuel.
c. Includes 1,167 truck shipments of DOE spent nuclear fuel and 300 railcar shipments of naval spent nuclear fuel.

Table J-7. High-level radioactive waste shipments by site.[a]

	Proposed Action		Module 1 or 2	
Site	Mostly truck[b]	Mostly rail[c]	Mostly truck[b]	Mostly rail[c]
INEEL[d]	0	0	1,292	260[e]
Hanford	1,960	392	14,500	2,900
Savannah River Site	6,055	1,211	6,188	1,238
West Valley[f]	300	60	300	60
Totals	***8,315***	***1,663***	***22,280***	***4,458***

a. The total U.S. inventory of high-level radioactive waste at the time of shipment would be 22,280 canisters. Under the Proposed Action, DOE would only ship 8,315 canisters. Under Inventory Module 1 or 2, DOE would ship the entire inventory.
b. One canister per shipment.
c. Five canisters per shipment.
d. INEEL = Idaho National Engineering and Environmental Laboratory.
e. 238 shipments of Idaho Nuclear Technology and Engineering Center glass form waste, 20 shipments of Argonne National Laboratory-West ceramic form waste, and 2 shipments of Argonne National Laboratory-West metallic form waste (see Appendix A, Section A.2.3.5.1).
f. High-level radioactive waste at West Valley is commercial rather than DOE waste.

J.1.2.1.3 *Greater-Than-Class-C and Special-Performance-Assessment-Required Waste Shipments*

Reasonably foreseeable future actions could include shipment of Greater-Than-Class-C and Special-Performance-Assessment-Required waste to the Yucca Mountain Repository (Appendix A describes Greater-Than-Class-C and Special-Performance-Assessment-Required wastes). Commercial nuclear powerplants, research reactors, radioisotope manufacturers, and other manufacturing and research institutions generate low-level radioactive waste that exceeds the Nuclear Regulatory Commission Class C shallow-land-burial disposal limits. In addition to DOE-held material, there are three other sources or categories of Greater-Than-Class-C low-level radioactive waste:

- Nuclear utilities
- Sealed sources
- Other generators

The activities of nuclear electric utilities and other radioactive waste generators to date have produced relatively small quantities of Greater-Than-Class-C low-level radioactive waste. As the utilities take their reactors out of service and decommission them, they could generate more waste of this type.

DOE Special-Performance-Assessment-Required low-level radioactive waste could include the following materials:

- Production reactor operating wastes
- Production and research reactor decommissioning wastes
- Non-fuel-bearing components of naval reactors
- Sealed radioisotope sources that exceed Class C limits for waste classification
- DOE isotope production-related wastes
- Research reactor fuel assembly hardware

The analysis estimated the number of shipments of Greater-Than-Class-C and Special-Performance-Assessment-Required waste by assuming that 10 cubic meters (about 350 cubic feet) would be shipped in a rail cask and 2 cubic meters (about 71 cubic feet) would be shipped in a truck cask. Table J-8 lists the resulting number of commercial Greater-Than-Class-C shipments in Inventory Module 2 for both truck and rail shipments. The shipments of Greater-Than-Class-C waste from commercial utilities would originate among the commercial reactor sites. Typically, boiling-water reactors would ship a total of about 9 cubic meters (about 318 cubic feet) of Greater-Than-Class-C waste per site, while pressurized-water reactors would ship about 20 cubic meters (about 710 cubic feet) per site (see Appendix A). The impacts of transporting this waste were examined for each reactor site. The analysis assumed that sealed sources and Greater-Than-Class-C waste identified as “other” would be shipped from the DOE Savannah River Site (see Table J-8).

Table J-8. Commercial Greater-Than-Class-C waste shipments.[a]

Category	Truck	Rail
Commercial utilities	742	210
Sealed sources	121	25
Other	233	47
Totals	***1,096***	***282***

a. Source: Appendix A.

The analysis assumed DOE Special-Performance-Assessment-Required waste would be shipped from four DOE sites listed in Table J-9. Naval reactor and Argonne East Special-Performance-Assessment-Required waste is assumed to be shipped from the Idaho National Engineering and Environmental Laboratory.

Table J-9. DOE Special-Performance-Assessment-Required waste shipments.[a]

Site[b]	Rail	Truck
Hanford	2	10
INEEL[c]	58	66
SRS (ORNL)	294	1,466
West Valley	56	276
Totals	***410***	***1,763***

a. Source: Appendix A; rounded.

b. Abbreviations: INEEL = Idaho National Engineering and Environmental Laboratory; SRS = Savannah River Site; ORNL = Oak Ridge National Laboratory.

c. Includes 55 rail shipments of naval Special-Performance-Assessment-Required waste. These shipments would travel by rail regardless of scenario.

J.1.2.1.4 *Sensitivity of Transportation Impacts to Number of Shipments*

As discussed in Section J.1.2.1, the number of shipments from commercial and DOE sites to the repository would depend on the mix of legal-weight truck and rail shipments. At this time, many years before shipments could begin, it is impossible to predict the mix with a reasonable degree of accuracy. Therefore, the analysis used two scenarios to provide results that bound the range of anticipated impacts. Thus, for a mix of legal-weight truck and rail shipments within the range of the mostly legal-weight truck and mostly rail scenarios, the impacts would be likely to lie within the bounds of the impacts predicted by the analysis. For example, a mix that is different from the scenarios analyzed could consist of 10,000 legal-weight truck shipments and 8,000 rail shipments over 24 years (compared to approximately 1,100 and 9,600, respectively, for the mostly rail scenario). In this example, the number of traffic fatalities would be between 3.1 (estimated for the Proposed Action under the mostly rail scenario) and 4.5 (estimated for the mostly legal-weight truck scenario). Other examples that have different mixes within the ranges bounded by the scenarios would lead to results that would be within the range of the evaluated impacts.

In addition to mixes within the brackets, the number of shipments could fall outside the ranges used for the mostly legal-weight truck and rail transportation scenarios. If, for example, the mostly rail scenario used smaller rail casks than the analysis assumed, the number of shipments would be greater. If spent nuclear fuel was placed in the canisters before they were shipped, the added weight and size of the canisters would reduce the number of fuel assemblies that a given cask could accommodate; this would increase the number of shipments. However, for the mostly rail scenario, even if the capacity of the casks was half that used in the analysis, the impacts would remain below those forecast for the mostly legal-weight truck scenario. Although impacts would be related to the number of shipments, because the number of rail shipments would be very small in comparison to the total railcar traffic on the Nation's railroads, increases or decreases would be small for impacts to biological resources, air quality, hydrology, noise, and other environmental resource areas. Thus, the impacts of using smaller rail casks would be covered by the values estimated in this EIS.

For legal-weight truck shipments, the use of casks carrying smaller payloads than those used in the analysis (assuming the shipment of the same spent nuclear fuel) would lead to larger impacts for incident-free transportation and traffic fatalities and about the same level of radiological accident risk. The relationship is approximately linear; if the payloads of truck shipping casks in the mostly legal-weight truck scenario were less by one-half, the incident-free impacts would increase by approximately a factor of 2. Conversely, because the amount of radioactive material in a cask would be less (assuming shipment of the same spent nuclear fuel), the radiological consequences of maximum reasonably foreseeable accident scenarios would be less with the use of smaller casks. If smaller casks were used to accommodate shipments of spent nuclear fuel with shorter cooling time and higher burnup, the radiological consequences of maximum reasonably foreseeable accident scenarios would be about the same.

J.1.2.2 Transportation Routes

At this time, about 10 years before shipments could begin, DOE has not determined the specific routes it would use to ship spent nuclear fuel and high-level radioactive waste to the proposed repository. Nonetheless, this analysis used current regulations governing highway shipments and historic rail industry practices to select existing highway and rail routes to estimate potential environmental impacts of national transportation. Routing for shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository would comply with applicable regulations of the U.S. Department of Transportation and the Nuclear Regulatory Commission in effect at the time the shipments occurred, as stated in the proposed DOE revised policy and procedures (DIRS 104741-DOE 1998, all) for implementing Section 180(c) of the Nuclear Waste Policy Act, as amended (NWPA).

Approximately 4 years before shipments to the proposed repository began, the Office of Civilian Radioactive Waste Management plans to identify the preliminary routes that DOE anticipates using in state and tribal jurisdictions so it can notify governors and tribal leaders of their eligibility for assistance under the provisions of Section 180(c) of the NWPA. DOE has published a revised proposed policy statement that sets forth its revised plan for implementing a program of technical and financial assistance to states and Native American tribes for training public safety officials of appropriate units of local government and tribes through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste (63 *FR* 23756, January 2, 1998) (see Appendix M, Section M.8).

The analysis of impacts of the Proposed Action and Modules 1 and 2 used characteristics of routes that shipments of spent nuclear fuel and high-level radioactive waste could travel from the originating sites listed in Tables J-4 through J-7. Existing routes that could be used were identified for the mostly legal-weight truck and mostly rail transportation scenarios and included the 10 rail and heavy-haul truck implementing alternatives evaluated in the EIS for transportation in Nevada. The route characteristics used were the transportation mode (highway, railroad, or navigable waterway) and, for each of the modes, the total distance between an originating site and the repository. In addition, the analysis estimated the fraction of travel that would occur in rural, suburban, and urban areas for each route. The fraction of travel in each population zone was determined using 1990 Census data (see Section J.1.1.2 and J.1.1.3) to identify population-zone impacts for route segments. The highway routes were selected for the analysis using the HIGHWAY computer program and routing requirements of the U.S. Department of Transportation for shipments of Highway Route-Controlled Quantities of Radioactive Materials (49 CFR 397.101). Shipments of spent nuclear fuel and high-level radioactive waste would contain Highway Route-Controlled Quantities of Radioactive Materials.

J.1.2.2.1 *Routes Used in the Analysis*

Routes used in the analysis of transportation impacts of the Proposed Action and Inventory Modules 1 and 2 are highways and rail lines that DOE anticipates it could use for legal-weight truck or rail shipments from each origin to Nevada. For rail shipments that would originate at sites not served by railroads, routes used for analysis include highway routes for heavy-haul trucks or barge routes from the sites to railheads. Figures J-5 and J-6 show the truck and rail routes, respectively, analyzed for the Proposed Action and Inventory Modules 1 and 2. Tables J-10 and J-11 list the lengths of trips and the distances of the highway and rail routes, respectively, in rural, suburban, and urban population zones. Sites that would be capable of loading rail casks, but that do not have direct rail access, are listed in Table J-11. The analysis used six ending rail nodes in Nevada (Beowawe, Caliente, Dry Lake, Eccles,

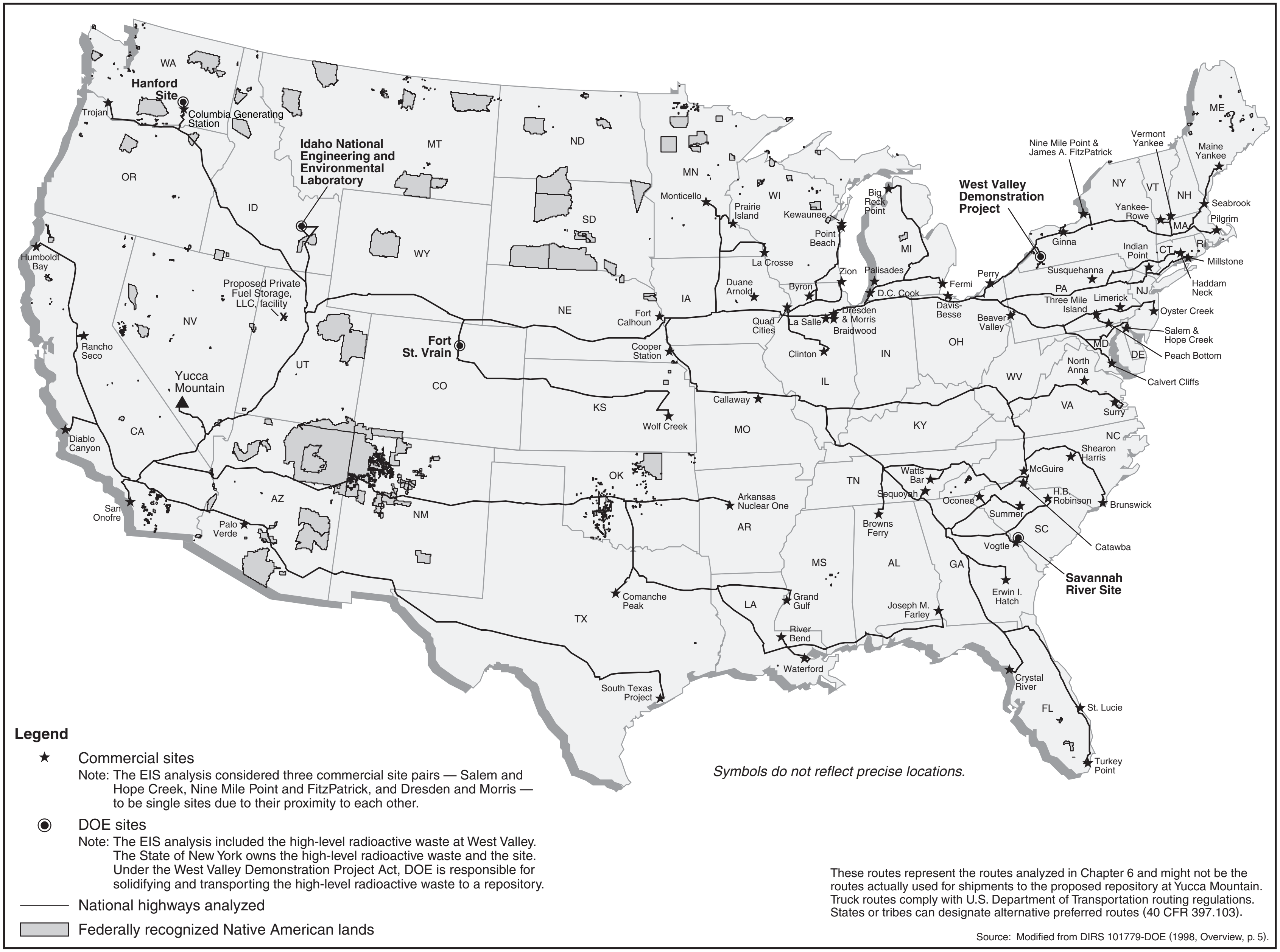

Figure J-5. Representative truck routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action and Inventory Modules 1 and 2.

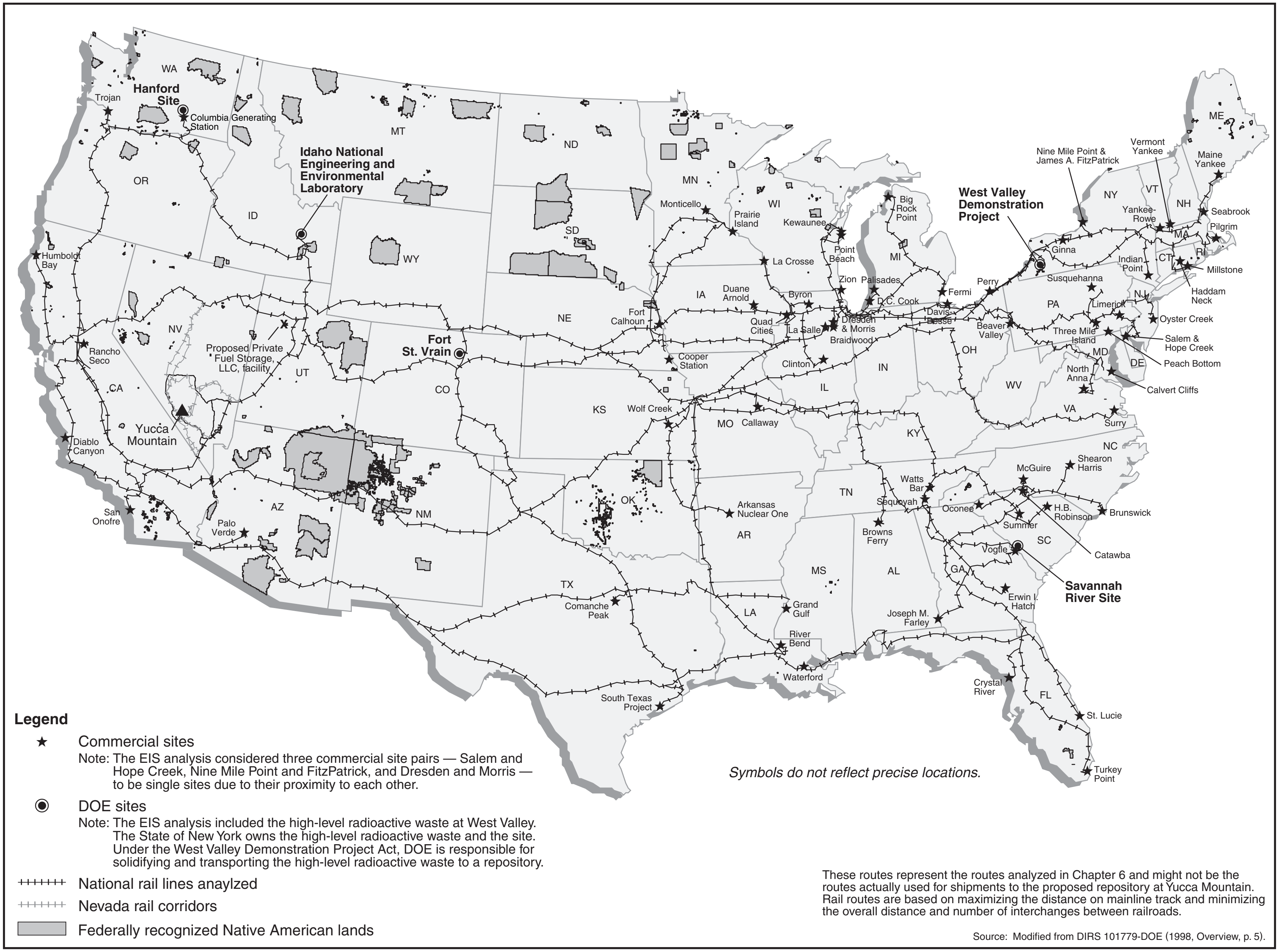

Figure J-6. Representative rail routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action and Inventory Modules 1 and 2.

Table J-10. Highway distances for legal-weight truck shipments from commercial and DOE sites to Yucca Mountain, mostly legal-weight truck transportation (kilometers)[a,b] (page 1 of 2).

Origin	State	Total[c]	Rural	Suburban	Urban
Browns Ferry	AL	3,798	3,344	393	61
Joseph M. Farley	AL	4,149	3,617	463	69
Arkansas Nuclear One	AR	2,810	2,588	191	30
Palo Verde	AZ	1,007	886	100	21
Diablo Canyon	CA	1,015	828	119	68
Humboldt Bay	CA	1,749	1,465	192	92
Rancho Seco	CA	1,228	1,028	124	76
San Onofre	CA	694	517	89	87
Haddam Neck	CT	4,519	3,708	736	75
Millstone	CT	4,527	3,673	746	109
Crystal River	FL	4,675	3,928	672	75
St. Lucie	FL	4,944	4,115	748	80
Turkey Point	FL	5,198	4,210	840	148
Edwin I. Hatch	GA	4,342	3,695	572	74
Vogtle	GA	4,294	3,623	592	79
Duane Arnold	IA	2,773	2,544	189	40
Braidwood	IL	3,063	2,796	231	36
Byron	IL	3,032	2,773	223	36
Clinton	IL	3,104	2,814	252	38
Dresden/Morris	IL	3,059	2,798	225	36
La Salle	IL	3,017	2,766	215	36
Quad Cities	IL	2,877	2,631	211	36
Zion	IL	3,167	2,834	284	50
Wolf Creek	KS	2,686	2,474	173	38
River Bend	LA	3,479	3,097	322	60
Waterford	LA	3,565	3,159	346	59
Pilgrim	MA	4,722	3,697	930	94
Yankee-Rowe	MA	4,615	3,692	831	92
Calvert Cliffs	MD	4,278	3,511	684	82
Maine Yankee	ME	4,894	3,733	1,052	108
Big Rock Point	MI	3,866	3,266	547	52
D. C. Cook	MI	3,196	2,827	318	51
Fermi	MI	3,524	3,014	449	61
Palisades	MI	3,244	2,855	338	51
Monticello	MN	3,003	2,702	261	41
Prairie Island	MN	2,993	2,720	232	41
Callaway	MO	2,988	2,721	225	43
Grand Gulf	MS	3,354	2,989	311	54
Brunswick	NC	4,773	3,994	696	82
Shearon Harris	NC	4,543	3,815	649	79
McGuire	NC	4,347	3,737	535	74
Cooper Station	NE	2,523	2,328	160	36
Fort Calhoun	NE	2,348	2,165	148	35
Seabrook	NH	4,725	3,675	942	107
Oyster Creek	NJ	4,424	3,530	825	69
Salem/Hope Creek	NJ	4,350	3,531	739	79
Ginna	NY	4,089	3,356	642	91
Indian Point	NY	4,382	3,695	620	67
James A. FitzPatrick/ Nine Mile Point	NY	4,234	3,461	688	85

Table J-10. Highway distances for legal-weight truck shipments from commercial and DOE sites to Yucca Mountain, mostly legal-weight truck transportation (kilometers)[a,b] (page 2 of 2).

Origin	State	Total[c]	Rural	Suburban	Urban
Davis-Besse	OH	3,520	3,106	358	55
Perry	OH	3,693	3,157	464	73
Trojan	OR	2,137	1,865	236	36
Beaver Valley	PA	3,779	3,214	500	64
Limerick	PA	4,287	3,484	741	62
Peach Bottom	PA	4,205	3,479	662	63
Susquehanna	PA	4,126	3,539	528	59
Three Mile Island	PA	4,147	3,443	643	60
Catawba	SC	4,350	3,686	594	70
Oconee	SC	4,208	3,586	551	71
H. B. Robinson	SC	4,467	3,739	647	81
Summer	SC	4,352	3,704	576	71
Sequoyah	TN	3,856	3,361	433	61
Watts Bar	TN	3,933	3,460	413	61
Comanche Peak	TX	2,794	2,547	213	34
South Texas	TX	3,011	2,652	295	64
North Anna	VA	4,437	3,825	533	79
Surry	VA	4,611	3,898	629	83
Vermont Yankee	VT	4,615	3,675	846	94
Colombia Generating Station	WA	1,880	1,669	178	32
Kewaunee	WI	3,347	2,978	314	55
La Crosse	WI	3,014	2,773	198	43
Point Beach	WI	3,341	2,972	314	55
Ft. St. Vrain[d]	CO	1,637	1,501	108	28
INEEL[e]	ID	1,201	1,044	129	27
West Valley[f]	NY	3,959	3,322	562	75
Savannah River[e]	SC	4,294	3,622	593	79
Hanford[e]	WA	1,881	1,671	178	32

a. To convert kilometers to miles, multiply by 0.62137.
b. Distances determined for purposes of analysis using HIGHWAY computer program.
c. Totals might differ from sums due to method of calculation and rounding.
d. DOE spent nuclear fuel site.
e. DOE spent nuclear fuel and high-level radioactive waste site.
f. High-level radioactive waste site.

Jean, and Apex) to select rail routes from the 77 sites. These rail nodes would be starting points for the rail and heavy-haul truck implementing alternatives analyzed for transportation in Nevada.

Selection of Highway Routes. The analysis of national transportation impacts used route characteristics of existing highways, such as distances, population densities, and state-level accident statistics. The analysis of highway shipments of spent nuclear fuel and high-level radioactive waste used the HIGHWAY computer model (DIRS 104780-Johnson et al. 1993, all) to determine highway routes using regulations of the U.S. Department of Transportation (49 CFR 397.101) that specify how routes are selected. The selection of "preferred routes" is required for shipment of these materials. DOE has determined that the HIGHWAY program is appropriate for calculating highway routes and related information (DIRS 101845-Maheras and Pippen 1995, pp. 2 to 5). HIGHWAY is a routing tool that DOE has used in previous EISs [for example, the programmatic EIS on spent nuclear fuel (DIRS 101802-DOE 1995, Volume 1, p. I-6) and the Waste Isolation Pilot Plant Supplement II EIS (DIRS 101814-DOE 1997, pp. 5 to 13)] to determine highway routes for impact analysis.

Table J-11. Rail transportation distances from commercial and DOE sites to Nevada ending rail nodes[a] (kilometers)[b,c] (page 1 of 3).

Site	Total[d]	Rural	Suburban	Urban
ommercial sites with direct rail access				
Arkansas Nuclear One	2,593 - 2,930	2,427 - 2,720	149 - 181	17 - 29
Beaver Valley	3,242 - 3,579	2,675 - 2,968	452 - 484	115 - 127
Braidwood	2,586 - 2,923	2,260 - 2,553	253 - 286	73 - 85
Brunswick	4,145 - 4,482	3,363 - 3,656	721 - 753	60 - 72
Byron	2,403 - 2,740	2,207 - 2,500	172 - 204	24 - 35
Catawba	3,819 - 4,156	3,265 - 3,559	495 - 527	59 - 70
Clinton	2,595 - 2,932	2,358 - 2,651	196 - 228	41 - 53
Columbia Generating Station	1,369 - 1,706	1,274 - 1,567	84 - 116	11 - 22
Comanche Peak	2,492 - 2,678	2,218 - 2,401	213 - 236	37 - 43
Crystal River	4,175 - 4,653	3,481 - 3,960	587 - 672	55 - 106
D. C. Cook	2,632 - 2,969	2,261 - 2,555	277 - 309	94 - 105
Davis Besse	2,917 - 3,254	2,452 - 2,745	356 - 389	109 - 121
Dresden/Morris	2,510 - 2,847	2,253 - 2,546	222 - 255	35 - 46
Duane Arnold	2,168 - 2,505	2,014 - 2,307	135 - 167	20 - 31
Edwin I. Hatch	3,929 - 4,266	3,396 - 3,689	480 - 513	53 - 64
Fermi	3,072 - 3,409	2,513 - 2,806	437 - 469	123 - 135
H. B. Robinson	3,889 - 4,226	3,137 - 3,430	685 - 717	68 - 79
Humboldt Bay	724 - 1,412	550 - 1,093	137 - 239	36 - 80
James A. FitzPatrick/Nine Mile Point	3,632 - 3,969	2,848 - 3,141	631 - 663	154 - 165
Joseph M. Farley	4,021 - 4,358	3,438 - 3,731	529 - 561	54 - 66
La Crosse	2,851 - 3,579	2,578 - 3,361	196 - 234	22 - 39
La Salle	2,653 - 3,381	2,396 - 3,179	181 - 220	20 - 37
Limerick	3,934 - 4,271	3,148 - 3,441	664 - 696	123 - 135
Maine Yankee	4,435 - 4,771	3,245 - 3,538	1,008 - 1,040	182 - 193
McGuire	3,916 - 4,253	3,170 - 3,463	679 - 712	66 - 78
Millstone	4,139 - 4,476	3,078 - 3,371	893 - 925	168 - 179
Monticello	2,655 - 2,822	2,347 - 2,543	241 - 265	38 - 44
North Anna	3,944 - 4,281	3,132 - 3,425	639 - 672	172 - 184
Palo Verde	872 - 1,466	778 - 1,113	77 - 252	18 - 101
Perry	3,222 - 3,558	2,836 - 3,129	317 - 349	69 - 80
Prairie Island	2,344 - 2,681	2,100 - 2,393	223 - 255	22 - 33
Quad Cities	2,595 - 3,323	2,324 - 3,108	194 - 233	21 - 38
Rancho Seco	263 - 882	178 - 694	61 - 139	24 - 48
River Bend	3,266 - 3,405	2,966 - 3,027	268 - 358	28 - 68
San Onofre	472 - 1,133	322 - 756	93 - 264	58 - 112
Seabrook	4,282 - 4,619	3,183 - 3,477	920 - 952	179 - 190
Sequoyah	3,366 - 3,703	3,044 - 3,337	277 - 309	46 - 57
Shearon Harris	4,046 - 4,383	3,301 - 3,595	686 - 718	59 - 70
South Texas	2,815 - 3,277	2,539 - 2,770	234 - 434	42 - 73
Summer	3,755 - 4,092	3,291 - 3,584	414 - 446	50 - 62
Susquehanna	3,827 - 4,164	2,883 - 3,176	771 - 803	173 - 185
Three Mile Island	3,828 - 4,165	3,129 - 3,422	588 - 620	111 - 123
Trojan	1,326 - 2,048	1,040 - 1,836	172 - 346	40 - 108
Vermont Yankee	4,078 - 4,415	3,135 - 3,429	778 - 811	164 - 176
Vogtle	3,985 - 4,322	3,443 - 3,736	489 - 522	53 - 64
Waterford	3,408 - 3,540	2,878 - 3,086	293 - 453	63 - 76
Watts Bar	3,310 - 3,647	3,011 - 3,304	254 - 286	46 - 57
Wolf Creek	2,108 - 2,445	1,995 - 2,288	98 - 130	15 - 27
Zion	2,542 - 2,879	2,231 - 2,525	247 - 279	64 - 75

Table J-11. Rail transportation distances from commercial and DOE sites to Nevada ending rail nodes[a] (kilometers)[b,c] (page 2 of 3).

Site	Total[d]	Rural	Suburban	Urban
ommercial sites with indirect rail access				
Big Rock Point				
HH[e]-20.0 kilometers	3,258 - 3,595	2,766 - 3,059	399 - 431	93 - 105
Browns Ferry				
HH-55.4 kilometers	3,118 - 3,455	2,723 - 3,016	353 - 386	42 - 53
Callaway				
HH-18.5 kilometers	2,230 - 2,567	2,103 - 2,396	108 - 140	20 - 32
Calvert Cliffs				
HH-41.9 kilometers	3,829 - 4,166	3,024 - 3,317	631 - 663	174 - 185
Cooper Station				
HH-53.8 kilometers	1,852 - 2,189	1,719 - 2,012	109 - 141	25 - 36
Diablo Canyon				
HH-43.5 kilometers	715 - 789	461 - 522	162 - 181	73 - 105
Fort Calhoun				
HH-6.0 kilometers	1,736 - 2,073	1,656 - 1,949	70 - 102	10 - 21
Ginna				
HH-35.1 kilometers	3,532 - 3,869	2,792 - 3,086	604 - 636	136 - 147
Grand Gulf				
HH-47.8 kilometers	3,108 - 3,445	2,817 - 3,115	259 - 373	28 - 67
Haddam Neck				
HH-16.6 kilometers	4,105 - 4,442	3,070 - 3,363	868 - 901	167 - 178
Hope Creek				
HH-51.0 kilometers	3,978 - 4,315	2,842 - 3,135	912 - 944	225 - 236
Indian Point				
HH-14.2 kilometers	3,981 - 4,318	3,034 - 3,327	781 - 813	166 - 177
Kewanee				
HH-9.7 kilometers	2,867 - 3,204	2,421 - 2,714	363 - 395	84 - 95
Oconee				
HH-17.5 kilometers	3,738 - 4,075	3,221 - 3,514	464 - 496	54 - 65
Oyster Creek				
HH-28.5 kilometers	4,061 - 4,398	2,862 - 3,155	957 - 989	242 - 254
Palisades				
HH-41.9 kilometers	2,680 - 3,017	2,279 - 2,572	306 - 338	96 - 107
Peach Bottom				
HH-58.9 kilometers	3,849 - 4,186	3,134 - 3,427	604 - 637	111 - 122
Pilgrim				
HH-8.7 kilometers	4,263 - 4,600	3,103 - 3,396	986 - 1,018	174 - 185
Point Beach				
HH-36.4 kilometers	2,820 - 3,157	2,405 - 2,698	338 - 370	78 - 89
Salem				
HH-51.0 kilometers	3,950 - 4,287	2,868 - 3,161	864 - 896	219 - 230
St. Lucie				
HH-23.5 kilometers	4,315 - 4,840	3,464 - 3,984	732 - 809	74 - 125
Surry				
HH-75.2 kilometers	4,065 - 4,402	3,468 - 3,761	523 - 555	74 - 85
Turkey Point				
HH-17.4 kilometers	4,662 - 5,140	3,696 - 4,175	785 - 870	127 - 179
Yankee-Rowe				
HH-10.1 kilometers	3,998 - 4,335	3,083 - 3,376	752 - 784	164 - 175

Table J-11. Rail transportation distances from commercial and DOE sites to Nevada ending rail nodes[a] (kilometers)[b,c] (page 3 of 3).

Site	Total[d]	Rural	Suburban	Urban
DOE spent nuclear fuel and high-level radioactive waste				
Ft. St. Vrain[f]	1,039 - 1,321	1,011 - 1,214	24 - 93	3 - 13
Hanford Site[g]	1,356 - 1,693	1,262 - 1,555	84 - 116	11 - 22
INEEL[g]	482 - 819	445 - 738	34 - 66	4 - 15
Savannah River Site[g]	3,751 - 4,088	3,081 - 3,374	605 - 638	65 - 76
West Valley[h]	3,447 - 3,784	2,774 - 3,067	538 - 570	135 - 146

a. The ending rail nodes (INTERLINE computer program designations) are Apex-14763; Caliente-14770; Beowawe-14791; and Jean-16328.
b. To convert kilometers to miles, multiply by 0.62137.
c. This analysis used the INTERLINE computer program to estimate distances.
d. Totals might differ from sums due to method of calculation and rounding.
e. HH = heavy-haul truck distance.
f. DOE spent nuclear fuel.
g. DOE spent nuclear fuel and high-level radioactive waste.
h. High-level radioactive waste.

Because the regulations require that the preferred routes result in reduced time in transit, changing conditions, weather, and other factors could result in the use of more than one route at different times for shipments between the same origin and destination. However, for this analysis the program selected only one route for travel from each site to the Yucca Mountain site. Section J.4 describes the highway routes used in the analysis along with estimated impacts of legal-weight truck shipments for each state.

Although shipments could use more than one preferred route in national highway transportation to comply with U.S. Department of Transportation regulations (49 CFR 397.101), under current U.S. Department of Transportation regulations all preferred routes would ultimately enter Nevada on Interstate 15 and travel to the repository on U.S. Highway 95. States or tribes can designate alternative or additional preferred routes for highway shipments (49 CFR 397.103). At this time the State of Nevada has not identified any alternative or additional preferred routes that DOE could use for shipments to the repository.

STATE-DESIGNATED PREFERRED ROUTES

U.S. Department of Transportation regulations specify that states and tribes can designate preferred routes that are alternatives, or in addition to, Interstate System highways including bypasses or beltways for the transportation of Highway Route-Controlled Quantities of Radioactive Materials. Highway Route-Controlled of Radioactive Materials include spent nuclear fuel and high-level radioactive waste in quantities that would be shipped on a truck or railcar to the repository. If a state or tribe designated such a route, highway shipments of spent nuclear fuel and high-level radioactive waste would use the preferred route if (1) it was an alternative preferred route, (2) it would result in reduced time in transit, or (3) it would replace pickup or delivery routes. Fourteen states have designated alternative or additional preferred routes (65 *FR* 75771; December 4, 2000). Although Nevada has designated a State routing agency to the Department of Transportation (Nevada Revised Statutes, Chapter 408.141), the State has not yet designated alternative or preferred routes for Highway Route-Controlled Quantities of Radioactive Materials. State route designations in the future could require changes in highway routes that would be used for shipments of spent nuclear fuel and high-level radioactive waste from 77 sites to Yucca Mountain. As an example of recent changes, two states notified the U.S. Department of Transportation of state-designated preferred routes (65 *FR* 75771; December 4, 2000) near or following publication of the Draft EIS.

Selection of Rail Routes. Rail transportation routing of spent nuclear fuel and high-level radioactive waste shipments is not regulated by the U.S. Department of Transportation. As a consequence, the routing rules used by the INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all) assumed that railroads would select routes using historic practices. DOE has determined that the INTERLINE program is appropriate for calculating routes and related information for use in transportation analyses (DIRS 101845-Maheras and Pippen 1995, pp. 2 to 5). Because the routing of rail shipments would be subject to future, possibly different practices of the involved railroads, DOE could use other rail routes. Section J.4 contains maps of the rail routes used in the analysis along with estimated impacts of rail shipments for each state.

For the 24 commercial sites that have the capability to handle and load rail casks but do not have direct rail service, DOE used the HIGHWAY computer program to identify routes for heavy-haul transportation to nearby railheads. For such routes, routing agencies in affected states would need to approve the transport and routing of overweight and overdimensional shipments.

J.1.2.2.2 *Routes for Shipping Rail Casks from Sites Not Served by a Railroad*

In addition to routes for legal-weight trucks and rail shipments, 24 commercial sites that are not served by a railroad, but that have the capability to load rail casks, could ship spent nuclear fuel to nearby railheads using heavy-haul trucks (see Table J-11). In addition, four of the sites that initially are legal-weight truck sites would be indirect rail sites after plant shutdown.

J.1.2.2.3 *Sensitivity of Analysis Results to Routing Assumptions*

Routing for shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository would comply with regulations of the U.S. Department of Transportation and the Nuclear Regulatory Commission in effect at the time shipments would occur. Unless the State of Nevada designates alternative or additional preferred routes, to comply with U.S. Department of Transportation regulations all preferred routes would ultimately enter Nevada on Interstate 15 and travel to the repository on U.S. Highway 95. States can designate alternative or additional preferred routes for highway shipments. At this time the State of Nevada has not identified any alternative or additional preferred routes DOE could use for shipments to the repository. Section J.3.1.3 examines the sensitivity of transportation impacts both nationally and regionally (within Nevada) to changes in routing assumption within Nevada.

J.1.3 ANALYSIS OF IMPACTS FROM INCIDENT-FREE TRANSPORTATION

DOE analyzed the impacts of incident-free transportation for shipments of commercial and DOE spent nuclear fuel and DOE high-level radioactive waste that would be shipped under the Proposed Action and Inventory Modules 1 and 2 from 77 sites to the repository. The analysis estimated impacts to the public and workers and included impacts of loading shipping casks at commercial and DOE sites and other preparations for shipment as well as intermodal transfers of casks from heavy-haul trucks or barges to rail cars.

J.1.3.1 Methods and Approach for Analysis of Impacts for Loading Operations

The analysis used methods and assessments developed for spent nuclear fuel loading operations at commercial sites to estimate radiological impacts to involved workers at commercial and DOE sites. Previously developed conceptual radiation shield designs for shipping casks (DIRS 101747-Schneider et al. 1987, Sections 4 and 5), rail and truck shipping cask dimensions, and estimated radiation dose rates at locations where workers would load and prepare casks (DIRS 104791-DOE 1992, p. 4.2) for shipment were the analysis bases for loading operations. In addition, tasks and time-motion evaluations from these studies were used to describe spent nuclear fuel handling and loading. These earlier evaluations were based on normal, incident-free operations that would be conducted according to Nuclear Regulatory Commission regulations that establish radiation protection criteria for workers.

The analysis assumed that noninvolved workers would not have tasks that would result in radiation exposure. In a similar manner, the analysis projected that the dose to the public from loading operations would be extremely small, resulting in no or small impacts. A separate evaluation of the potential radiation dose to members of the public from loading operations at commercial nuclear reactor facilities showed that the dose would be very low, less than 0.001 person-rem per metric ton uranium of spent nuclear fuel loaded (DIRS 104731-DOE 1986, p. 2.42, Figure 2.9). Public doses from activities at commercial and DOE sites generally come from exposure to airborne emissions and, in some cases, waterborne effluents containing low levels of radionuclides. However, direct radiation at publicly accessible locations near these sites typically is not measurable and contributes negligibly to public dose and radiological impacts. Though DOE expects no releases from loading operations, this analysis estimated that the dose to the public would be 0.001 person-rem per metric ton uranium, and metric ton equivalents, for DOE spent nuclear fuel and high-level radioactive waste. Noninvolved workers could also be exposed to low levels of radioactive materials and radioactivity from loadout operations. However, because these workers would not work in radiation areas they would receive a very small fraction of the dose received by involved workers. DOE anticipates that noninvolved workers would receive individual doses similar to those received by members of the public. Because the population of noninvolved workers would be small compared to the population of the general public near the 77 sites, the dose to these workers would be a small fraction of the public dose.

The analysis used several basic assumptions to evaluate impacts from loading operations at DOE sites:

- Operations to load spent nuclear fuel and high-level radioactive waste at DOE facilities would be similar to loading operations at commercial facilities.

- Commercial spent nuclear fuel would be in storage pools or in dry storage at the reactors and DOE spent nuclear fuel would be in dry storage, ready to be loaded directly in Nuclear Regulatory Commission-certified shipping casks and then on transportation vehicles. In addition, DOE high-level radioactive waste could be loaded directly in casks. All preparatory activities, including packaging, repackaging, and validating the acceptability of spent nuclear fuel for acceptance at the repository would be complete prior to loading operations.

- Commercial spent nuclear fuel to be placed in the shipping casks would be uncanistered or canistered fuel assemblies, with at least one assembly in a canister. DOE spent nuclear fuel and high-level radioactive waste would be in disposable canisters. Typically, uncanistered assemblies would be loaded into shipping casks under water in storage pools (wet storage). Canistered spent nuclear fuel could be loaded in casks directly from dry storage facilities or storage pools.

In addition, because handling and loading operations for DOE spent nuclear fuel and high-level radioactive waste and commercial spent nuclear fuel would be similar, the analysis assumed that impacts to workers during the loading of commercial spent nuclear fuel could represent those for the DOE materials, even though the radionuclide inventory of commercial fuel and the resultant external dose rate would be higher than those of the DOE materials. This conservative assumption of selecting impacts from commercial handling and loading operations overestimated the impacts of DOE loading operations, but it enabled the use of detailed real information developed for commercial loading operations to assess impacts for DOE operations. Equivalent information was not available for operations at DOE facilities. To gauge the conservatism of the assumption DOE compared the radioactivity of contents of shipments of commercial and DOE spent nuclear fuel and high-level radioactive waste. Table J-12 compares typical inventories of important contributors to the assessment of worker and public health impacts. These are cesium-137 and actinide isotopes (including plutonium) for rail shipments of commercial spent nuclear

Table J-12. Average cesium-137, actinide isotope, and total radioactive material content (curies) in a rail shipping cask.[a]

Material	Cesium-137	Actinides	Total (all isotopes)
Commercial spent nuclear fuel (PWR)[b]	816,000	694,000	2,130,000
High-level radioactive waste	27,000	53,000[c]	180,000
DOE spent nuclear fuel (except naval spent nuclear fuel)	119,000	40,000	265,000
Naval spent nuclear fuel	450,000	28,000	1,100,000

a. Source: Appendix A. Source estimated based on 24 typical pressurized-water reactor fuel assemblies for commercial spent nuclear fuel; one dual-purpose shipping canister for naval spent fuel; nine canisters of DOE spent nuclear fuel; and five canisters of high-level radioactive waste.

b. PWR = pressurized-water reactor.

c. Includes immobilized plutonium with high-level radioactive waste.

fuel, DOE spent nuclear fuel, and DOE high-level radioactive waste. Although other factors are also important (for example, material form and composition), these indicators provide an index of the relative hazard potential of the materials. Appendix A contains additional information on the radionuclide inventory and characteristics of spent nuclear fuel and high-level radioactive waste.

J.1.3.1.1 *Radiological Impacts of Loading Operations at Commercial Sites*

In 1987, DOE published a study of the estimated radiation doses to the public and workers resulting from the transport of spent nuclear fuel from commercial nuclear power reactors to a hypothetical deep geologic repository (DIRS 101747-Schneider et al. 1987, all). This study was based on a single set of spent nuclear fuel characteristics and a single split [30 percent/70 percent by weight; 900 metric tons uranium/2,100 metric tons uranium per year] between truck and rail conveyances. DOE published its findings on additional radiological impacts on monitored retrievable storage workers in an addendum to the 1987 report (DIRS 104791-DOE 1992, all). The technical approaches and impacts summarized in these DOE reports were used to project involved worker impacts that would result from commercial at-reactor spent nuclear fuel loading operations. DOE did not provide a separate analysis of noninvolved worker impacts in these reports. For the analysis in this EIS, DOE assumed that noninvolved workers would not receive radiation exposures from loading operations. This assumption is appropriate because noninvolved workers would be personnel with managerial or administrative support functions directly related to the loading tasks but at locations, typically in offices, away from areas where loading activities took place.

In the DOE study, worker impacts from loading operations were estimated for a light-water reactor with pool storage of spent nuclear fuel. The radiological characteristics of the spent nuclear fuel in the analysis was 10-year-old, pressurized-water reactor fuel with an exposure history (burnup) of 35,000 megawatt-days per metric ton. In addition, the reference pressurized-water reactor and boiling-water reactor fuel assemblies were assumed to contain 0.46 and 0.19 MTU, respectively, prior to reactor irradiation. The term MTU (metric ton of uranium) is from the DOE study. An MTU is approximately the same quantity of spent nuclear fuel as a metric ton of heavy metal, or MTHM, as described in this EIS. In this section, the terms are used interchangeably to allow the information reported in prior DOE studies to be used without modification. These parameters for spent nuclear fuel are similar to those presented in Appendix A of this EIS. The use of the parameters for spent nuclear fuel presented in Appendix A would be likely to lead to similar results.

In the 1987 study, radiation shielding analyses were done to provide information on (1) the conceptual configuration of postulated reference rail and truck transportation casks, and (2) the direct radiation levels at accessible locations near loaded transportation casks. The study also presented the results of a detailed time-motion analysis of work tasks that used a loading concept of operations. This task analysis was coupled with cask and at-reactor direct radiation exposure rates to estimate radiation doses to involved workers (that is, those who would participate directly in the handling and loading of the transportation casks and conveyances). Impacts to members of the public from loading operations had been shown to be small [fraction of a person-millirem population dose; (DIRS 101747-Schneider et al. 1987, p. 2.9)] and were eliminated from further analysis in the 1987 report. The at-reactor-loading concept of operations included the following activities:

1. Receiving the empty transportation cask at the site fence
2. Preparing and moving the cask into the facility loading area
3. Removing the cask from the site prime mover trailer
4. Preparing the cask for loading and placing it in the water-filled loading pit
5. Transferring spent nuclear fuel from its pool storage location to the cask
6. Removing the cask from the pool and preparing it for shipment
7. Placing the cask on the site prime mover trailer
8. Moving the loaded cask to the site fence where the trailer is connected to the transportation carrier's prime mover for offsite shipment

The results for loading operations are listed in Table J-13.

Table J-13. Principal logistics bases and results for the reference at-reactor loading operations.[a]

Parameter	Conveyance		
	Rail[b]	Truck[c]	Total
Annual loading rate (MTU/year)[d]	2,100	900	3,000
Transportation cask capacity, PWR - BWR (MTU/cask)	6.5 - 6.7	0.92 - 0.93	NA[e]
Annual shipment rate (shipments/year)	320	970	1,290
Average loading duration,[f] PWR - BWR (days)	2.3 - 2.5	1.3 - 1.4	NA
Involved worker specific CD,[g] PWR - BWR (person-rem/MTU)	0.06 - 0.077	0.29 - 0.31	NA

a. Source: DIRS 101747-Schneider et al. (1987, pp. 2.5 and 2.7).
b. 14 pressurized-water reactor and boiling-water reactor spent nuclear fuel assemblies per rail transportation cask.
c. 2 pressurized-water reactor and boiling-water reactor spent nuclear fuel assemblies per truck transportation cask.
d. MTU = metric tons of uranium. One MTU is approximately equal to 1 MTHM.
e. NA = not applicable.
f. Based on single shift operations; carrier drop-off and pick-up delays were not included.
g. Collective dose expressed as the sum of the doses accumulated by all loading (involved) workers, regardless of the total number of workers assigned to loading tasks.

The loading activities that the study determined would produce the highest collective unit impacts are listed in Table J-14. As listed in this table, the involved worker collective radiation doses would be dominated by tasks in which the workers would be near the transportation cask when it contained spent nuclear fuel, particularly when they were working around the cask lid area. These activities would deliver at least 40 percent of the total collective worker doses. Worker impacts from the next largest dose-producing tasks (working to secure the transportation cask on the trailer) would account for 12 to 19 percent of the total impact. The impacts are based on using crews of 13 workers [the number of workers

Table J-14. At-reactor reference loading operations—collective impacts to involved workers.[a]

Task description	Rail: CD per MTU[b,c] (PWR - BWR)[d]	Rail: Percent of total impact	Truck: CD per MTU (PWR - BWR)	Truck: Percent of total impact
Install cask lids; flush cask interior; drain, dry and seal cask	0.025 - 0.024	40 - 31	0.126 - 0.126	43 - 40
Install cask binders, impact limiters, personnel barriers	0.010 - 0.009	15 - 12	0.056 - 0.055	19 - 18
Load SNF into cask	0.011 - 0.027	17 - 35	0.011 - 0.027	4 - 9
On-vehicle cask radiological decontamination and survey	0.003 - 0.003	5 - 4	0.018 - 0.018	6 - 6
Final inspection and radiation surveys	0.002 - 0.002	4 - 3	0.016 - 0.015	5 - 5
All other (19) activities	0.011 - 0.012	19 - 16	0.066 - 0.073	23 - 23
Task totals	*0.062 - 0.077*	*100 - 100*	*0.29 - 0.31*	*100 - 100*

a. Source: DIRS 101747-Schneider et al. (1987, p. 2.9).
b. CD/MTU = Collective dose (person-rem effective dose equivalent) per metric ton uranium. One MTU is approximately equal to 1 MTHM.
c. The at-reactor loading crew size is assumed to be 13 involved workers.
d. PWR = pressurized-water reactor; BWR = boiling-water reactor.

assumed in the DIRS 101747-Schneider et al. (1987, Section 2) study] dedicated solely to performing cask-handling work. The involved worker collective dose was calculated using the following formula:

$$\text{Collective dose (person-rem)} = A \times B \times C \times D \times E$$

where: A = number of pressurized-water or boiling-water reactor spent nuclear fuel shipments being analyzed under each transportation scenario (from Tables J-4 and J-5)

B = number of transportation casks included in a shipment (set at 1 for both transportation scenarios)

C = number of pressurized-water or boiling-water reactor spent nuclear fuel assemblies in a transportation cask (from Table J-3)

D = amount of uranium in the spent nuclear fuel assembly prior to reactor irradiation, expressed as metric tons uranium per assembly (from Table J-13)

E = involved worker-specific collective dose in person-rem/metric ton uranium for each fuel type (from Table J-13)

Because worker doses are linked directly to the number of loading operations performed, the highest average individual doses under each transportation scenario would occur at the reactor sites having the most number of shipments. Accordingly, the average individual dose impacts were calculated for the limiting site using the equation:

$$\text{Average individual dose (rem per involved worker)} = (A \times B \times C \times D \times E) \div F$$

where: A = largest value for the number of shipments from a site under each transportation scenario (from Tables J-4 and J-5)

B = number of transportation casks included in a shipment (set at 1 for both transportation scenarios)

C = number of spent nuclear fuel assemblies in a transportation cask (from Table J-3)

D = amount of uranium in the spent nuclear fuel assembly prior to reactor irradiation in metric tons uranium per assembly (from Table J-13)

E = involved worker-specific collective dose in person-rem per metric ton uranium for each fuel type (from Table J-13)

F = involved worker crew size (set at 13 persons for both transportation scenarios; from Table J-14)

J.1.3.1.2 *Radiological Impacts of DOE Spent Nuclear Fuel and High-Level Radioactive Waste Loading Operations*

The methodology used to estimate impacts to workers during loading operations for commercial spent nuclear fuel was also used to estimate impacts of loading operations for DOE spent nuclear fuel and high-level radioactive waste. The exposure factor (person-rem per MTU) for loading boiling-water reactor spent nuclear fuel in truck casks at commercial facilities was used (see Table J-14). The exposure factor for truck shipments of boiling-water reactor spent nuclear fuel was based on a cask capacity of five boiling-water reactor spent nuclear fuel assemblies (about 0.9 MTU or 0.9 MTHM). The analysis used this factor because it would result in the largest estimates for dose per operation.

J.1.3.2 Methods and Approach for Analysis of Impacts from Incident-Free Transportation

The potential exists for human health impacts to workers and members of the public from incident-free transportation of spent nuclear fuel and high level radioactive waste. *Incident-free* transportation means normal accident-free shipment operations during which traffic accidents and accidents in which radioactive materials could be released do not occur (Section J.1.4. discusses accidents). Incident-free impacts could occur from exposure to (1) external radiation in the vicinity of the transportation casks, or (2) transportation vehicle emissions, both during normal transportation.

J.1.3.2.1 *Incident-Free Radiation Dose to Populations*

The analysis used the RADTRAN 5 computer model and program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) to evaluate incident-free impacts for populations. The RADTRAN 5 input parameters used to estimate incident-free impacts are listed in Table J-15. Through extensive review (DIRS 101845-Maheras and Pippen 1995, Section 3 and 4), DOE has determined that this program provides reasonable, but conservative, estimates of population doses for use in the evaluation of risks of transporting radioactive materials, including spent nuclear fuel and high-level radioactive waste. DOE used the previous version, RADTRAN 4, to analyze transportation impacts for other environmental impact statements (for example, DIRS 101802-DOE 1995, Volume 1, Appendix E; DIRS 101816-DOE 1997, Appendixes F and G). RADTRAN 4 was subjected to extensive review (DIRS 101845-Maheras and Pippen 1995, Sections 3 and 4). RADTRAN 5 is an upgrade to RADTRAN 4, and has been validated by comparison with dose measurements (DIRS 153967-Steinman and Kearfott 2000, all). RADTRAN 5 consistently overestimates doses from transported radioactive materials when the results are compared to measured doses. The program and associated database, using population densities from 1990 Census data escalated to 2035, calculated the collective dose to populations that live along transportation routes [within 800 meters (0.5 mile) of either side of the route]. Table J-16 lists the estimated number of people who live within 800 meters of national routes.

Table J-15. Input parameters and parameter values used for the incident-free national truck and rail transportation analysis, except stops.

Parameter	Legal-weight truck transportation	Rail transportation	Legal-weight truck and rail
Package type			Type B shipping cask
Package dimension	5.2 meters[a] long 1.0 meters diameter	5.06 meters long 2.0 meters diameter	
Dose rate			10 millirem per hour, 2 meters from side of vehicle[f]
Number of crewmen	2	5	
Distance from source to crew	3.1 meters[a]	152 meters[b]	
Speed			
Rural	88 km[c,d] per hour	64 km per hour	
Suburban	88 km/hr non-rush hour 44 km/hr rush hour	40 km per hour	
Urban	88 km/hr non-rush hour 44 km/hr rush hour	24 km per hour	
Input for stop doses: see Table J-17			
Number of people per vehicle sharing route	2	3	
Minimum and maximum distances to exposed population			30 meters to 800 meters
Population densities (persons per km^2)[d]			
Rural			(e)
Suburban			(e)
Urban			(e)
One-way traffic count (vehicles per hour)			
Rural	470	1	
Suburban	780	5	
Urban	2,800	5	

a. To convert meters to feet, multiply by 3.2808.
b. Rail crew in transit would be too far and too well shielded from the external cask radiation to receive any dose. This number is not used in the calculation and is provided for information only.
c. To convert kilometers to miles, multiply by 0.62137.
d. Assumes general freight rather than dedicated service.
e. Population densities along transportation routes were estimated using the HIGHWAY and INTERLINE computer programs, then were extrapolated to 2035.
f. The actual (equivalent) input to RADTRAN 5 is 14 millirem per hour at 1 meter (3.3 feet) from the side of the vehicle.

Table J-16. Population within 800 meters (0.5 mile) of routes for incident-free transportation using 2035 population.

Transportation scenario	2035 population
Mostly legal-weight truck	10,400,000
Mostly rail	16,400,000

RADTRAN 5 uses the following information to estimate collective incident-free doses to the public:

- The external radiation dose rate around shipping casks
- The resident population density (number of people per square kilometer) in the census block groups that contain the route (from HIGHWAY or INTERLINE)
- In urban areas, a factor for nonresident population density
- The speed of the vehicle (truck or train)
- The number of shipments that would be transported over each route
- The density of vehicles (number of vehicles per kilometer) sharing the route with the shipment and the average number of people in each vehicle
- Conditions at vehicle stops, which are described in greater detail below.

Most of these parameters were developed using the data listed in Tables J-15 and J-17. The number of shipments that would use a transportation route was developed with the use of the CALVIN computer program discussed in Section J.1.1.1, the DOE Throughput Study (DIRS 100265-CRWMS M&O 1997, Section 6.1.1), data on DOE spent nuclear fuel and high-level radioactive waste inventories in Appendix A, and data from DOE sites (DIRS 104778-Jensen 1998, all). The analysis used CALVIN to estimate the number of shipments from each commercial site. The Throughput Study provided the estimated number of shipments of high-level radioactive waste from the four DOE sites. Information provided by the DOE National Spent Nuclear Fuel Program (DIRS 104778-Jensen 1998, all) and in Appendix A was used to estimate shipments of DOE spent nuclear fuel.

The analysis used a value of 10 millirem per hour at a distance of 2 meters (6.6 feet) from the side of a transport vehicle for the external dose rate around shipping casks. This value is the maximum allowed by regulations of the U.S. Department of Transportation for shipments of radioactive materials [49 CFR 173.441(b)]. Dose rates at distances greater than 2 meters from the side of a vehicle would be less. The dose rate at 30 meters (98 feet) from the vehicle would be less than 0.2 millirem per hour; at a distance of 800 meters (2,600 feet) the dose rate would be less than 0.0002 millirem per hour.

In addition, the analysis used RADTRAN 5 to estimate doses to people closer to the cask than the resident population along the route, and to people who would be exposed for longer periods of time. These populations would include the truck or rail crew, others working near the cask, people in vehicles that share the route with the shipment, members of the public at truck stops, and residents of the area near the truck and rail stops.

The analysis also uses the potential number of people close enough to shipments to be exposed to radiation from the casks. The analysis determined the estimated offlink number of people [those within the 1.6-kilometer (1-mile) region of influence] by multiplying the population densities (persons per square kilometer) in population zones through which a route would pass by the 1.6-kilometer width of the region of influence and by the length of the route through the population zones. Onlink populations (those sharing the route and people at stops along the route) were estimated using assumptions from other EISs that have evaluated transportation impacts (DIRS 101802-DOE 1995, Volume 1, Appendix I; DIRS 101812-DOE 1996, Appendix E; DIRS 101816-DOE 1997, Appendixes F and G). The travel distance in each population zone was determined for legal-weight truck shipments by using the HIGHWAY computer program (DIRS 104780-Johnson et al. 1993, all) and for rail shipments by using the INTERLINE

Table J-17. Input parameter values for stop doses for routine incident-free transportation.

Stop type	Population exposed	Minimum distance (meters)[a]	Maximum distance (meters)[a]	Stop time	Other
Doses to the public					
People at truck stops	6.9[b]	1[b]	15.8[b]	20 min[b]	845 km[c] between stops
Residents near truck stops	Rural, suburban, or urban[d]	30	800	20 min[b]	845 km between stops
Residents near truck walkaround inspections[e]	Rural, suburban, or urban	30	800	10 min	161 km between stops
Residents near rail classification stops	Rural, suburban, or urban	30	800	30 hr[a]	One stop at each end of trip
Residents near rail crew change stops	Rural, suburban, or urban	30	800	0.033 hr/km[b]	
Occupational stop doses					
Truck crew dose at rest/refuel stops	2	1	15.8	20 min	845 km between stops
Truck crew dose at walkaround inspectons	1	1	1	10 min	161 km between stops
	1	Dose rate = 2 mrem/hr by regulation			
Rail crew dose at classification stops	5	(e)		30 hr	One stop at each end of trip
Rail crew dose at crew change stops	5	Calculated by multiplying the classification stop dose by 0.0018/km: a distance-dependent worker exposure factor[f]			

a. To convert meters to feet, multiply by 3.2808.
b. Derived from DIRS 152084-Griego, Smith, and Neuhauser (1996, all).
c. km = kilometer; to convert kilometers to miles, multiply by 0.62137.
d. Values used in DIRS 152476-Sprung et al. (2000, pp. 3-5 to 3-9, Table 3.3).
e. DIRS 155430-Neuhauser, Kanipe, and Weiner (2000, Appendix B) explains this calculation, which has been incorporated into RADTRAN 5.
f. DIRS 150898-Neuhauser and Kanipe (2000, pp. 51 to 52).

program (DIRS 104781-Johnson et al. 1993, all). These programs used 1990 census block group data to identify where highways and railroads enter and exit each type of population zone, which the analysis used to determine the total lengths of the highways and railroads in each population zone.

The third kind of information—the distances individuals live from the route used in the analysis—is the estimated the number of people who live within 800 meters (about 2,600 feet) of the route. The analysis assumed that population density is uniform in population zones.

The analysis used RADTRAN 5 to calculate exposures for the following groups:

- *Public along the route (Offlink Exposure):* Collective doses for persons living or working within 0.8 kilometer (0.5 mile) on each side of the transportation route.

- *Public sharing the route (Onlink Exposure):* Collective doses for persons in vehicles sharing the transportation route; this includes persons traveling in the same or opposite direction and those in vehicles passing the shipment.

- *Public during stops (Stops):* Collective doses for people who could be exposed while a shipment was stopped en route. For truck transportation, these would include stops for refueling, food, and rest and for brief inspections at regular intervals. For rail transportation, stops would occur in railyards at the beginning and end of each trip, and along the route to switch railcars from inbound trains to outbound trains traveling toward the Yucca Mountain site, and to change train crews and equipment (locomotives).

- *Worker exposure (Occupational Exposure):* Collective doses for truck and rail transportation crew members.

- *Security escort exposure (Occupational Exposure):* Collective doses for security escorts. In calculating doses to workers the analysis conservatively assumed that the maximum number of escorts required by regulations (10 CFR 73.37) would be present for urban, suburban, and rural population zones.

The sum of the doses for the first three categories is the total nonoccupational (public) dose.

The sensitivity analysis in Section J.1.3.2.2.3 evaluates impacts of requiring additional escorts such as escorts in separate vehicles for all parts of every shipment of loaded legal-weight truck casks and two escorts in all areas for rail shipments.

Table J-17 lists input parameter values for doses to public and workers at stops. RADTRAN 5 models stops separately, and does not use the "hours per kilometer of travel" of the RADTRAN 4 model. Documentation for a stop model for dose to the public at truck rest and refueling stops is in DIRS 152084-Griego, Smith, and Neuhauser (1996, all). Models for calculating doses to members of the public who reside near stops, as well as occupational doses, for truck and rail, are in DIRS 152476-Sprung et al. (2000, pp. 8-14 to 8-18). For each model, the analysis includes a population or population density component, a total stop-time component, and the calculation, using RADTRAN 5, of an "hour per kilometer" equivalent for consistency with the unit risk factors listed in Table J-18. The external dose rate from the cask for all stops is 10 millirem per hour at 2 meters (6.6 feet) from the cask.

Unit dose factors were used to calculate incident-free collective doses. The offlink unit risk factors listed in Table J-18 represent the dose that would be received by a population density of one person per square kilometer for one shipment of radioactive material moving a distance of 1 kilometer (0.62 mile) in the indicated population density zone, and reflect the assumption that the dose rate external to shipments of spent nuclear fuel and high-level radioactive waste would be the maximum value allowed by U.S. Department of Transportation regulations—10 millirem per hour at 2 meters (6.6 feet) from the side of the transport vehicle (49 CFR 173.441). The onlink unit risk factors represent the doses that would be received by occupants of vehicles sharing the transportation route with the cargo. There are two kinds of stop dose unit risk factors: one for the resident population near stops, based on a population density of one person per square kilometer, and another for the public at rest and refueling stops, which is independent of population density. The incident-free dose from transporting a single shipment was determined by multiplying the appropriate unit dose factors by corresponding distances in each of the population zones through which the shipment route would pass and by the population density of the zone. The collective dose from all shipments from a site was determined by multiplying the dose from a single shipment by the number of shipments that would be required to transport the site's spent nuclear fuel or high-level radioactive waste to the repository. Collective dose was converted to the estimated number of latent cancer fatalities using conversion factors recommended by the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, p. 22). These values are 0.0004 latent cancer fatality per person-rem for radiation workers and 0.0005 latent cancer fatality per person-rem for the general population.

J.1.3.2.2 *Methods Used To Evaluate Incident-Free Impacts to Maximally Exposed Individuals*

To estimate impacts to maximally exposed individuals, the same kinds of information as those used for population doses (except for population size) were needed. The analysis of doses to maximally exposed individuals used projected exposure times, the distance a hypothetical individual would be from a shipment, the number of times an exposure event could occur, and the assumed external radiation dose

Table J-18. Incident-free dose factors.

Factor		Barge	Heavy-haul truck	Rail	Legal-weight truck
Public					
Off-link[a] [rem per (persons per square kilometer) per kilometer]	Rural	1.72×10^{-7}	6.24×10^{-8}	3.90×10^{-8}	2.98×10^{-8}
	Suburban	1.72×10^{-7}	6.24×10^{-8}	6.24×10^{-8}	3.18×10^{-8}
	Urban	1.72×10^{-7}	6.24×10^{-8}	1.04×10^{-7}	3.18×10^{-8}
On-link[b] (person-rem per kilometer)	Rural		1.01×10^{-4}	1.21×10^{-7}	9.53×10^{-6}[(c)]
	Suburban		7.94×10^{-5}	1.55×10^{-6}	2.75×10^{-5}
	Urban		2.85×10^{-4}	4.29×10^{-6}	9.88×10^{-5}
Residents near rest/refueling stops (rem per person per kilometer)[d]	Rural		3.96×10^{-9}	1.24×10^{-7}	5.50×10^{-9}
	Suburban		3.96×10^{-9}	1.24×10^{-7}	5.50×10^{-9}
	Urban		3.96×10^{-9}	1.24×10^{-7}	5.50×10^{-9}
Residents near classification stops (rem per person per square kilometer)	Suburban			1.59×10^{-5}	
Public including workers at rest/ refueling stops (person-rem per kilometer)					7.86×10^{-6}
Workers					
Classification stops (person-rem)				8.07×10^{-3}	
In-transit rail stops (person-rem per kilometer)				1.45×10^{-5}	
In moving vehicle (person-rem per kilometer)	Rural	2.11×10^{-6}	5.54×10^{-6}		4.52×10^{-5}
	Suburban	2.11×10^{-6}	5.54×10^{-6}		4.76×10^{-5}
	Urban	2.11×10^{-6}	5.54×10^{-6}		4.76×10^{-5}
Walkaround inspection (person-rem per kilometer)			6.27×10^{-7}		1.93×10^{-5}

a. Offlink general population includes persons in the census block groups on the route; the population density in each census block group is assumed to be the population density in the half-mile on either side of the route.
b. Onlink general population included persons sharing the road or railway.
c. Onlink dose factors are larger than offlink because the onlink population (vehicles and persons per vehicle) is included in the dose factor, and because the vehicles are much closer to the radioactive cargo.
d. The methodology, equations, and data used to develop the unit dose factors are discussed in DIRS 152084-Griego, Smith, and Neuhauser (1996, all); DIRS 155430-Neuhauser, Kanipe, and Weiner (2000, Chapter 3); and DIRS 152476-Sprung et al. (2000, Chapter 3).

rate 2 meters (6.6 feet) from a shipment (10 millirem per hour). These analyses used the RISKIND computer program (DIRS 101483-Yuan et al. 1995, all). DOE has used RISKIND for analyses of transportation impacts in other environmental impact statements (DIRS 104382-DOE 1995, Appendix J; DIRS 101812-DOE 1996, Appendix E; DIRS 101816-DOE 1997, Appendix E). RISKIND provides appropriate results for analyses of incident-free transportation and transportation accidents involving radioactive materials (DIRS 101845-Maheras and Pippen 1995, Sections 5.2 and 6.2; DIRS 102060-Biwer et al. 1997, all).

The maximally exposed individual is a hypothetical person who would receive the highest dose. Because different maximally exposed individuals can be postulated for different exposure scenarios, the analysis evaluated the following exposure scenarios.

- *Crew Members.* In general, truck crew members, would receive the highest doses during incident-free transportation (see discussions below). The analysis assumed that the crews would be limited to a total job-related exposure of 2 rem per year (DIRS 156764-DOE 1999, Article 211).

- *Inspectors (Truck and Rail).* Inspectors would be Federal or state vehicle inspectors. On the basis of information provided by the Commercial Vehicle Safety Alliance (DIRS 104597-Battelle 1998, all;

DIRS 156422-CVSA 2001, all), the analysis assumed an average exposure distance of 1 meter (3 feet) and an exposure duration of 1 hour (see discussion in J.1.3.2.2.2).

- *Railyard Crew Member.* For a railyard crew member working in a rail classification yard assembling trains, the analysis assumed an average exposure distance of 10 meters (33 feet) and an exposure duration of 2 hours (DIRS 101816-DOE 1997, p. E-50).

- *Resident.* The analysis assumed this maximally exposed individual is a resident who lives 30 meters (100 feet) from a point where shipments would pass. The resident would be exposed to all shipments along a particular route (DIRS 101802-DOE 1995, Volume 1, Appendix I, p. I-52).

- *Individual Stuck in Traffic (Truck or Rail).* The analysis assumed that a member of the public could be 1.2 meter (4 feet) from the transport vehicle carrying a shipping cask for 1 hour. Because these circumstances would be random and unlikely to occur more than once for the same individual, the analysis assumed the individual to be exposed only once.

- *Resident Near a Rail Stop.* The analysis assumed a resident who lives within 200 meters (660 feet) of a switchyard and an exposure time of 20 hours for each occurrence. The analysis of exposure for this maximally exposed individual assumes that the same resident would be exposed to all rail shipments to the repository (DIRS 101802-DOE 1995, Volume 1, Appendix I, p. I-52).

- *Person at a Truck Service Station.* The analysis assumed that a member of the public (a service station attendant) would be exposed to shipments for 49 minutes for each occurrence at a distance of 16 meters (52 feet) (DIRS 152084-Griego, Smith, and Neuhauser 1996, all). The analysis also assumed this individual would work at a location where all truck shipments would stop.

As discussed above for exposed populations, the analysis converted radiation doses to estimates of radiological impacts using dose-to-risk conversion factors of the International Commission on Radiological Protection.

J.1.3.2.2.1 Estimation of Incident-Free Maximally Exposed Individuals in Nevada. This section presents the assumptions used to estimate incident-free exposures to maximally exposed individuals in Nevada.

Transporting spent nuclear fuel to the Yucca Mountain site by legal-weight or heavy-haul trucks would require transport through Nevada on existing roads and highways. The proximity of existing structures that could house a maximally exposed individual have been determined and the maximally exposed individual identified and potential dose calculated as discussed in Section J.1.3.2.2. DOE considered a number of different sources of information concerning the proximity of the maximally exposed individual to a passing truck carrying spent nuclear fuel or high-level radioactive waste.

- An analysis prepared for the City of North Las Vegas (DIRS 155112-Berger 2000, p. 104) locates the maximally exposed individual 15 meters (50 feet) from an intersection. This individual would be exposed for 1 minute per shipment and an additional 30 minutes per year due to traffic delays. DOE believes the conditions listed greatly exceed actual conditions that would be encountered. Nevertheless, the estimated dose to this maximally exposed individual would be 530 millirem over 24 years.

- DOE performed a survey to determine the location of and proximity to the proposed routes that identified potential maximally exposed individual locations as follows:

  - Residences approximately 5 meters (15 feet) from Highway 93 in Alamo, Nevada (DIRS 155825-Poston 2001, p. 10). The analysis estimated the dose to a maximally exposed individual at this location based on 10,000 heavy-haul truck shipments over 24 years. This estimated dose would be 25 millirem.

- The courthouse and fire station in Goldfield, Nevada, are 5.5 and 4.9 meters (18 and 15 feet), respectively (DIRS 155825-Poston 2001, p. 12) from the road. The analysis estimated the dose to maximally exposed individuals at this location assuming potential exposure to 10,000 heavy-haul truck shipments over 24 years. The estimated dose would be 56 millirem.

- The width of the cleared area for a branch rail line would be 60 meters (200 feet); therefore, the closest resident would be at least 30 meters (98 feet) from a branch rail line. A maximally exposed individual who would be a minimum distance of 30 meters from a branch rail line, assuming 10,000 shipments over 24 years, would receive an estimated dose of 2 millirem.

- The *Intermodal and Highway Transportation of Low-Level Radioactive Waste to the Nevada Test Site* (DIRS 155779-DOE 1999, VI pc-23, Table C-11) identifies the maximally exposed individual as residing between Barstow, California, and the Nevada Test Site approximately 10.7 meters (35 feet) from a highway over 24 years of shipments; this individual would receive an estimated 20 millirem.

As identified above, the maximally exposed individual dose over 24 years for transportation in Nevada would range from 2 to 530 millirem.

J.1.3.2.2.2 Incident-Free Radiation Doses to Inspectors. DOE estimated radiation doses to the state inspectors who would inspect shipments of spent nuclear fuel and high-level radioactive waste originating in, passing through, or entering a state. For legal-weight truck and railcar shipments, the analysis assumed that:

- Each inspection would involve one individual working for 1 hour at a distance of 1 meter (3.3 feet) from a shipping cask.

- The radiation field surrounding the cask would be the maximum permitted by regulations of the U.S. Department of Transportation (49 CFR 173.441).

- There would be no shielding between an inspector and a cask.

For rail shipments, the analysis assumed that:

- There would be a minimum of two inspections per trip—one at origin and one at destination—with additional inspections en route occurring at intermediate stops.

- Rail crews would conduct the remaining along-the-route inspections.

For legal-weight truck shipments, the analysis assumed that:

- On average, state officials would conduct two inspections during each trip – one at the origin and one at the destination.

- The inspectors would use the Enhanced North American Uniform Inspection Procedures and Out-of-Service Criteria for Commercial Highway Vehicles Transporting Transuranics, Spent Nuclear Fuel, and High-Level Radioactive Waste (DIRS 156422-CVSA 2001, all).

- The shipments would receive a Commercial Vehicle Safety Alliance inspection sticker on passing inspection and before departing from the 77 sites.

- Display of such a sticker would provide sufficient evidence to state authorities along a route that a shipment complied with U.S. Department of Transportation regulations (unless there was contradictory evidence), and there would be no need for additional inspections.

The analysis used the RISKIND computer program (DIRS 101483-Yuan et al. 1995, all) to determine doses to state inspectors. The data used by the program to calculate dose includes the estimated value for dose rate at 1 meter (3.3 feet) from a cask surface, the length and diameter of the cask, the distance between the location of the individual and the cask surface, and the estimated time of exposure. For rail shipments, using the assumptions outlined above, the estimated value for whole-body dose to an individual inspector for one inspection would be 17 millirem. Under the mostly rail scenario in which approximately 400 rail shipments would arrive in Nevada annually, a Nevada inspector working 1,800 hours per year could inspect as many as 82 shipments in a year. This inspector would receive a dose of 1.4 rem. If this same inspector inspected 82 shipments per year over the 24 years of the Proposed Action, he or she would be exposed to 34 rem.

The use of the dose-to-risk conversion factors published by the International Commission on Radiation Protection projects this exposure to increase the likelihood of the inspector incurring a fatal cancer. The projection would add 2 percent to the likelihood for fatal cancers from all other causes, increasing the likelihood from approximately 23 percent (DIRS 153066-Murphy 2000, p. 5) to 25 percent.

For shipments by legal-weight truck, the analysis used the RISKIND computer program to estimate doses to inspectors (DIRS 101483-Yuan et al. 1995, all). The data used by the program to calculate dose includes the estimated value for dose rate at 1 meter (3.3 feet) from a cask surface, the length and diameter of the cask, the distance between the location of the individual and the cask surface, and the estimated time of exposure. For this calculation, the analysis assumed that an inspector following Commercial Vehicle Safety Alliance procedures (DIRS 156422-CVSA 2001, all) would work for 1 hour at an average distance of 1 meter (3.3 feet) from the cask. The analysis assumed that a typical legal-weight truck cask would be about 1 meter in diameter and about 5 meters (16 feet) long and that the dose rate 1 meter from the cask surface would be 14 millirem per hour. A dose rate of 14 millirem per hour 1 meter from the surface of a truck cask is approximately equivalent to the maximum dose rate allowed by U.S. Department of Transportation regulations for exclusive-use shipments of radioactive materials (49 CFR 173.441).

Using these data, the RISKIND computer program calculated an expected dose of 18 millirem for an individual inspector. Under the mostly legal-weight truck scenario in which approximately 2,200 legal-weight truck shipments would arrive in Nevada annually, a Nevada inspector working 1,800 hours per year could inspect as many as 450 shipments in a year. This inspector would receive a dose of 8.1 rem. If this same inspector inspected all shipments over the 24 years of the Proposed Action, he or she would be exposed to approximately 200 rem. However, DOE would control worker exposure through administrative procedures (see DIRS 156764-DOE 1999, Article 211). Actual worker exposure would likely be 2 rem per year, or a maximum of 48 rem over 24 years. The use of the dose-to-risk conversion factors published by the International Commission on Radiation Protection projects this exposure to increase the likelihood of this individual contracting a fatal cancer. The projection would add about 2 percent to the likelihood for fatal cancers from all other causes, increasing the likelihood from approximately 23 percent (DIRS 153066-Murphy 2000, p. 5) to 25 percent. As discussed below, however, doses to inspectors likely would be much smaller.

DOE implements radiation protection programs at its facilities where there is the potential for worker exposure to cumulative doses from ionizing radiation. The Department anticipates that the potential for individual whole-body doses such as those reported above would lead an involved state to implement such a radiation protection program. If similar to those for DOE facilities, the administrative control limit on individual dose would not exceed 2 rem per year (DIRS 156764-DOE 1999, Article 211), and the expected maximum exposure for inspectors would be less than 500 millirem per year.

Under the mostly legal-weight truck scenario, the annual dose to inspectors in a state that inspected all incoming legal-weight truck shipments containing spent nuclear fuel or high-level radioactive waste would be as much as 40 person-rem. Over 24 years, the population dose for these inspectors would be about 950 person-rem. This would result in about 0.38 latent cancer fatality (this is equivalent to a 47-percent likelihood that there would be 1 additional latent cancer fatality among the exposed group).

The EIS analysis assumed that shipments would be inspected in the state of origin and in the destination state. If each state required an inspection on entry, the total occupational dose over 24 years of operation for the mostly legal-weight truck scenario would increase from approximately 14,000 person-rem to approximately 21,000 person-rem, resulting in an additional 3 latent cancer fatalities to the occupationally exposed population.

J.1.3.2.2.3 Incident-Free Radiation Doses to Escorts. This section has been moved to Volume IV of this EIS.

J.1.3.2.3 *Vehicle Emission Impacts*

Human health impacts from exposures to vehicle exhaust depend principally on the distance traveled and on the impact factors for fugitive dust and exhaust particulates from truck (including escort vehicles) or rail emissions (DIRS 151198-Biwer and Butler 1999, all; DIRS 155786-EPA 1997, all; DIRS 155780-EPA 1993, all).

The analysis estimated incident-free impacts using unit risk factors that account for fatalities associated with emissions of pollution in urban, suburban, and rural areas by transportation vehicles, including escort vehicles. Because the impacts would occur equally for trucks and railcars transporting loaded or unloaded shipping casks, the analysis used round-trip distances. Escort vehicle impacts were included only for loaded truck shipment miles, but were included for round trips for rail escort cars.

The analysis used risk factors to estimate impacts. The factors considered the effects of population density near highways and railroads. For urban areas, the value used for truck transportation was about 5 latent fatalities per 100 million kilometers traveled (8 latent fatalities per 100 million miles) by trucks and 2 latent fatalities per 10 million kilometers traveled by railcars (3 latent fatalities per 10 million miles). For trucks traveling in suburban and rural areas, the respective risk factors used are about 3 latent fatalities in 100 million kilometers (5 in 100 million miles) and 3 in 10 billion kilometers (5 in 10 billion miles). For railcars traveling in suburban and rural areas, the respective risk factors used are about 9 latent fatalities in 100 million kilometers (1.5 in 10 million miles) and about 8 in 10 billion kilometers (1.5 in 1 billion miles).

Although the analysis estimated human health and safety impacts of transporting spent nuclear fuel and high-level radioactive waste, exhaust and other pollutants emitted by transport vehicles into the air would not measurably affect national air quality. National transportation of spent nuclear fuel and high-level radioactive waste, which would use existing highways and railroads, would average 14.2 million truck kilometers per year for the mostly truck case and 3.5 million railcar kilometers per year from the mostly rail case. The national yearly average for total highway and railroad traffic is 186 billion truck kilometers and 49 billion railcar kilometers (DIRS 148081-BTS 1999, Table 3-22). Spent nuclear fuel and high-level radioactive waste transportation would represent a very small fraction of the total national highway and railroad traffic (0.008 percent of truck kilometers and 0.007 percent of rail car kilometers). In addition, the contributions to vehicle emissions in the Las Vegas air basin, where all truck shipments (an average of five per day) would travel under the mostly legal-weight truck scenario, would be small in comparison to those from other vehicle traffic in the area. The annual average daily traffic on I-15 0.3 kilometer (0.2 mile) north of the Sahara Avenue interchange is almost 200,000 vehicles (DIRS 103405-NDOT 1997, p. 7), about 20 percent of which are trucks (DIRS 104727-Cerocke 1998, all). For these reasons, national transportation of spent nuclear fuel and high-level radioactive waste by truck and rail would not constitute a meaningful source of air pollution along the nation's highways and railroads.

J.1.3.2.4 *Sensitivity of Dose Rate to Characteristics of Spent Nuclear Fuel*

For this analysis, DOE assumed that the dose rate external to all shipments of spent nuclear fuel and high-level radioactive waste would be the maximum value allowed by regulations (49 CFR 173.441). However, the dose rate for actual shipments would not be the maximum value of 10 millirem per hour at 2 meters (6.6 feet) from the sides of vehicles. Administrative margins of safety that are established to compensate for limits of accuracy in instruments and methods used to measure dose rates at the time shipments are made would result in lower dose rates. In addition, the characteristics of spent nuclear fuel and high-level radioactive waste that would be loaded into casks would always be within the limit values allowed by the cask's design and its Nuclear Regulatory Commission certificate of compliance.

For example, DOE used data provided in the *GA-4 Legal-Weight Truck Cask Design Report* (DIRS 101831-General Atomics 1993, pp. 5.5-18 and 5.5-19) to estimate dose rates 2 meters (6.6 feet) from transport vehicles for various characteristics of spent nuclear fuel payloads. Figure J-7 shows ranges of burnup and cooling times for spent nuclear fuel payloads for the GA-4 cask. The figure indicates the characteristics of a typical pressurized-water reactor spent nuclear fuel assembly (see Appendix A). Based on the design data for the GA-4 cask, a shipment of typical pressurized-water reactor spent nuclear fuel would result in a dose rate of about 6 millirem per hour at 2 meters from the side of the transport vehicle, or about 60 percent of the limit established by U.S. Department of Transportation regulations (49 CFR 173.441). Therefore, DOE estimates that, on average, dose rates at locations 2 meters (6.6 feet) from the sides of transport vehicles would be about 50 to 70 percent of the regulatory limits. As a result, DOE expects radiological risks to workers and the public from incident-free transportation to be no more than 50 to 70 percent of the values presented in this EIS.

J.1.4 METHODS AND APPROACH TO ANALYSIS OF ACCIDENT SCENARIOS

J.1.4.1 Accidents in Loading Operations

J.1.4.1.1 *Radiological Impacts of Loading Accidents*

The analysis used information in existing reports to consider the potential for radiological impacts from accidents during spent nuclear fuel loading operations at the commercial and DOE sites. These included a report that evaluated health and safety impacts of multipurpose canister systems (DIRS 104794-CRWMS M&O 1994, all) and two safety analysis reports for onsite dry storage of commercial spent nuclear fuel at independent spent fuel storage installations (DIRS 103449-PGE 1996, all; DIRS 103177-CP&L 1989, all). The latter reports address the handling and loading of spent nuclear fuel assemblies in large casks similar to large transportation casks. In addition, DOE environmental impact statements on the management of spent nuclear fuel and high-level radioactive waste (DIRS 101802-DOE 1995, all; DIRS 101816-DOE 1997, all) provided information on radiological impacts from loading accidents.

DIRS 104794-CRWMS M&O (1994, Sections 3.2 and 4.2) discusses potential accident scenario impacts of four cask management systems at electric utility and other spent nuclear fuel storage sites. This report concentrated on unplanned contact (bumping) during lift-handling of casks, canisters, or fuel assemblies. The two safety analysis reports for independent spent fuel storage installations for commercial spent

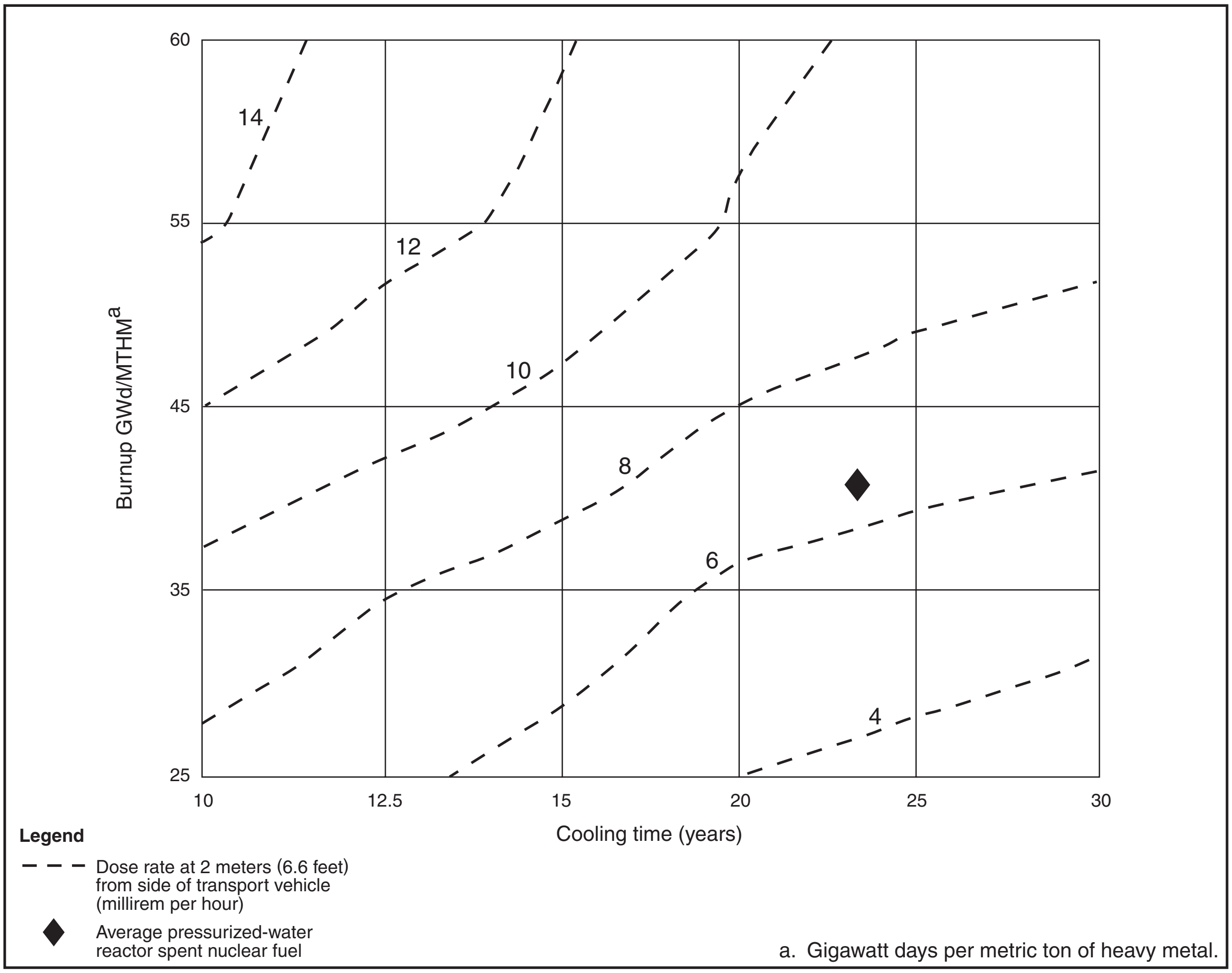

Figure J-7. Comparison of GA-4 cask dose rate and spent nuclear fuel burnup and cooling time.

nuclear fuel (DIRS 103449-PGE 1996, all; DIRS 103177-CP&L 1989, all) evaluated a comprehensive spectrum of accident-initiating events. These events included fires, chemical explosions, seismic events, nuclear criticality, tornado strikes and tornado-generated missile impacts, lightning strikes, volcanism, canister and basket drop, loaded shipping cask drop, and interference (bumping, binding) between the transfer cask and storage module. The DOE environmental impact statements for the interim management of spent nuclear fuel and high-level radioactive waste (DIRS 101802-DOE 1995, Volume 1, Appendix E; DIRS 101816-DOE 1997, Appendixes F and G) included radiological impacts from potential accident scenarios associated with preparing, storing, and shipping these materials. These EISs do not discuss quantitative radiological impacts for accident scenarios associated with material loading, but do contain estimates of radiological impacts from accident scenarios for the spent nuclear fuel and high-level radioactive waste management activities considered. As discussed for routine loading operations, this analysis converted radiation doses to estimates of radiological impacts using dose-to-risk conversion factors of the International Commission on Radiological Protection.

J.1.4.1.2 *Industrial Safety Impacts of Loading Operations at Commercial Facilities*

The principal industrial safety impact parameters of importance to commercial industry and the Federal Government are (1) total recordable (injury and illness) cases, (2) lost workday cases associated with workplace injuries and illnesses, and (3) workplace fatalities. The frequency of these impacts under the

Proposed Action and the inventory modules (Modules 1 and 2) was projected using the involved worker level of effort, expressed as the number of full-time equivalent worker multiples, that would be needed to conduct shipment tasks. The workplace loss incidence rate for each impact parameter [as shown in a Bureau of Labor Statistics summary (DIRS 148091-BLS 1998, all)] was used as a multiplier to convert the level of effort to expected industrial safety losses.

DOE did not explicitly analyze impacts to noninvolved workers in its earlier reports (DIRS 101747-Schneider et al. 1987, all; DIRS 104791-DOE 1992, all). However, for purposes of analysis in this EIS, DOE estimated that impacts to noninvolved workers would be 25 percent of the impacts to the involved workforce. This assumption is based on (1) the DOE estimate that about one of five workers assigned to a specific task would perform administrative or managerial duties, and (2) the fact that noninvolved worker loss incidence rates are generally less than those for involved workers (see Appendix F, Section F.2.2.2).

The estimated involved worker full-time equivalent multiples for each shipment scenario were estimated using the following formula:

$$\text{Involved worker full-time equivalent multiples} = (A \times B \times C \times D) \div E$$

where: A = number of shipments (from Tables J-5 and J-6)

B = average loading duration for each shipment by fuel type and conveyance mode (workdays; from Table J-13)

C = workday conversion factor = 8 hours per workday

D = involved worker crew size (13 workers; from Table J-14)

E = full-time equivalent conversion factor = 2,000 worker hours per full-time equivalent

The representative Bureau of Labor Statistics loss incidence rate for each total recordable case, lost workday case, and fatality trauma category (for example, the number of total recordable cases per full-time equivalent) was then multiplied by the involved worker full-time equivalent multiples to project the associated incidence. The involved worker total recordable case incidence rate used was that reported for the Trucking and Warehousing sector for 1998 because neither the Nuclear Regulatory Commission nor the Bureau of Labor Statistics maintains data on commercial power reactor industrial safety losses. The total recordable case incidence rate, 145,700 cases in a workforce of 1.74 million workers (8.4 total recordable cases per 100 full-time equivalents), is the averaged loss experience for 1998. The Trucking and Warehousing sector was chosen because DOE assumed the industrial operations and hazards associated with activities in this sector would be representative of those encountered in handling spent nuclear fuel casks at commercial power reactor sites and DOE facilities. Because lost workday cases are linked to the total recordable case experience (that is, each lost workday case would have to be included in the total recordable case category), the same period of record and facilities was used in the selection of the involved worker lost workday case incidence rate [80,800 lost workday cases in a workforce of 1.74 million workers (4.6 lost workday cases per 100 full-time equivalents)].

The DIRS 104794-CRWMS M&O (1994, all) study concluded that radiological impacts from handling incidents would be small. The population dose (person-rem) for accidents in handling the four cask systems considered in the study would vary from 0.1 rem to 0.04 rem. This dose would be the total for all persons who would be exposed, onsite workers as well as the public. The highest estimated dose (0.1 person-rem) could result in 0.00005 latent cancer fatality in the exposed population.

The involved worker fatality incidence rate reported by the Bureau of Labor Statistics (1.8 fatalities among 100,000 workers) for the Trucking and Warehousing sector during the DIRS 148091-BLS (1998, all) period of record was used.

DOE used the same Bureau of Labor Statistics data sources to estimate total recordable case, lost workday case, and fatality incidence rates for noninvolved workers.

J.1.4.1.3 *Industrial Safety Impacts of DOE Loading Operations*

The technical approach and loss multipliers discussed in Section J.1.4.1.2 for commercial power reactor sites analysis were used for the analysis of spent nuclear fuel and high-level radioactive waste loading impacts at DOE sites. Because no information existed on the high-level radioactive waste loading duration for the truck and rail transportation modes, DOE assumed that the number of full-time equivalent involved workers for the two transportation modes would be the same as that for the DOE sites shipping spent nuclear fuel. For those sites, the average number of full-time equivalent workers would be about 0.07 and 0.12 per shipment for the truck and rail transportation modes, respectively.

J.1.4.2 Transportation Accident Scenarios

J.1.4.2.1 *Radiological Impacts of Transportation Accidents*

Potential consequences and risks of transportation would result from three possible types of accidents: (1) accidents in which there is no effect on the cargo and the safe containment by transportation packages is maintained, (2) accidents in which there is no breach of containment, but there is loss of shielding because of lead shield displacement, and (3) accidents that release and disperse radioactive material from safe containment in transportation packages. Such accidents, if they occurred, would lead to impacts to human health and the environment. The following sections describe the methods for analyzing the risks and consequences of accidents that could occur in the course of transporting spent nuclear fuel and high-level radioactive waste to a nuclear waste repository at the Yucca Mountain site. They discuss the bases for, and methods for, determining rates at which accidents are assumed to occur, the severity of these accidents, and the amounts of materials that could be released. Accident rates, severities, and the corresponding quantities of radioactive materials that could be released are essential data used in the analyses. Appendix A presents the quantities of radioactive materials in a typical pressurized-water reactor spent nuclear fuel assembly used in the analysis of accident consequences and risks. Legal-weight truck casks would usually contain four pressurized-water reactor spent nuclear fuel assemblies, and rail casks would usually contain 24 (see Table J-3).

In addition to accident rates and severities, an important variable in assessing impacts from transportation accident scenarios is the type of material that would be shipped. Accordingly, this appendix presents information used in the analyses of impacts of accidents that could occur in the course of transporting commercial pressurized- and boiling-water reactor fuels, DOE spent nuclear fuels, and DOE high-level radioactive waste.

For exposures to ionizing radiation and radioactive materials following accidents, risks were analyzed in terms of dose and latent cancer fatalities to the public and workers. The analyses of risk also addressed the potential for fatalities that would be the direct result of mechanical forces and other nonradiological effects that occur in everyday vehicle and industrial accidents.

The transportation of spent nuclear fuel and high-level radioactive waste from the 77 sites to the Yucca Mountain site would be conducted in a manner that complied fully with regulations of the U.S. Department of Transportation and Nuclear Regulatory Commission. These regulations specify requirements that promote safety and security in transportation. The requirements apply to carrier

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POTENTIAL EFFECTS OF HUMAN ERROR ON ACCIDENT IMPACTS

The accident scenarios described in this chapter would be mostly a direct consequence of error on the part of transport vehicle operators, operators of other vehicles, or persons who maintain vehicles and rights-of-way. The number and severity of the accidents would be minimized through the use of trained and qualified personnel.

Others have argued that other kinds of human error could also contribute to accident consequences: (1) undetected error in the design and certification of transportation packaging (cask) used to ship radioactive material, (2) hidden or undetected defects in the manufacture of these packages, and (3) error in preparing the packages for shipment. DOE has concluded that regulations and regulatory practices of the Nuclear Regulatory Commission and the Department of Transportation address the design, manufacture, and use of transportation packaging and are effective in preventing these kinds of human error by requiring:

- Independent Nuclear Regulatory Commission review of designs to ensure compliance with requirements (10 CFR Part 71)
- Nuclear Regulatory Commission-approved and audited quality assurance programs for design, manufacturing, and use of transportation packages

In addition, Federal provisions (10 CFR Part 21) provide additional assurance of timely and effective actions to identify and initiate corrective actions for undetected design or manufacturing defects. Furthermore, conservatism in the approach to safety incorporated in the regulatory requirements and practices provides confidence that design or manufacturing defects that might remain undetected or operational deficiencies would not lead to a meaningful reduction in the performance of a package under normal or accident conditions of transportation.

operations; in-transit security; vehicles; shipment preparations; documentation; emergency response; quality assurance; and the design, certification, manufacture, inspection, use, and maintenance of packages (casks) that would contain the spent nuclear fuel and high-level radioactive waste.

Because of the high level of performance required by regulations for transportation casks (49 CFR Part 173 and 10 CFR Part 71), the Nuclear Regulatory Commission estimates that in more than 99.99 percent of rail and truck accidents no cask contents would be released (DIRS 152476-Sprung et al. 2000, pp. 7-73 to 7-76). The 0.007 percent of accidents, including those for which there is no release and those that could cause a release of radioactive materials, can be described by a spectrum of accident severity. In general, as the severity of an accident increases, the fraction of radioactive material contents that could be released from transportation casks also increases. However, as the severity of an accident increases it is generally less likely to occur. DIRS 152476-Sprung et al. (2000, all) developed an accident analysis methodology that uses this concept of a spectrum of severe accidents to calculate the probabilities and consequences of accidents that could occur in transporting highly radioactive materials.

The analysis in DIRS 152476-Sprung et al. (2000, pp. 7-74 and 7-76), which DOE adopted for the analysis in the EIS, estimates that 0.01 percent of accidents to steel-lead-steel casks could result in some lead displacement and consequent loss of shielding. The analysis evaluated the radiological impacts (population dose risk) of shielding loss and the impacts of potential releases of radioactive material. The loss-of-shielding analysis included estimates of radiological impacts for the percentage of accidents in which there would be neither loss of shielding nor release of radioactive material. In such accidents, the vehicle carrying the spent nuclear fuel would be stopped along the route for an extended period and nearby residents would not be evacuated.

Although the approach of DIRS 152476-Sprung et al. (2000, pp. 7-7 to 7-12), which is used in this EIS, provides a method for determining the frequency with which severe accidents can be expected to occur, their severity, and their consequences, a method does not exist for predicting where along routes accidents would occur. Therefore, the analyses of impacts presented here used the approach used in RADTRAN 5 (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all). This method assumes that accidents could occur at any location along routes, with their frequency of occurrence being determined by the accident rate characteristic of the states through which the route passes, the length of the route, and the number of shipments that travel the route.

The transportation accident scenario analysis evaluated radiological impacts to populations and to hypothetical maximally exposed individuals and estimated fatalities that could occur from traffic accidents. It included both rail and legal-weight truck transportation. The analysis used the RADTRAN 5 (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) and RISKIND (DIRS 101483-Yuan et al. 1995, all) models and computer programs to determine accident consequences and risks. DOE has used both codes in recent DOE environmental impact statements (DIRS 101802-DOE 1995, Volume 1, Appendix J; DIRS 101812-DOE 1996, Appendix E; DIRS 101816-DOE 1997, Appendixes F and G) that address impacts of transporting radioactive materials. The analyses used the following information to determine the consequences and risks of accidents for populations:

- Routes from the 77 sites to the repository and their lengths in each state and population zone
- The number of shipments that would be transported over each route
- State-specific accident rates
- The kind and amount of radioactive material that would be transported in shipments
- The type of cask used in spent nuclear fuel and high-level radioactive waste transportation
- Probabilities of amount of lead displacement that would result in loss of shielding
- Probabilities of release and fractions of cask contents that could be released in accidents
- The number of people who could be exposed to radiological material from accidents and how far they lived from the routes
- The length of time people could be exposed to external radiation in accidents that do not involve releases of radioactive material
- Exposure scenarios that include multiple exposure pathways, state-specific agricultural factors, and atmospheric dispersion factors for neutral and stable conditions applicable to the entire country for calculating radiological impacts

The analysis used the same routes and lengths of travel as the analysis of incident-free transportation impacts discussed above.

DOE used the CALVIN computer code discussed earlier, the DOE Throughput Study (DIRS 100265-CRWMS M&O 1997, all), and information provided by the DOE National Spent Nuclear Fuel Program (DIRS 104778-Jensen 1998, all) to calculate the number of shipments from each site and, thus, the number of shipments that would use a particular route.

TRANSPORTATION ACCIDENT RADIOLOGICAL DOSE RISK

The risk to the general public of radiological consequences from transportation accidents is called *dose risk* in this EIS. Dose risk is the sum of the products of the probabilities (dimensionless) and the consequences (in person-rem) of all potential transportation accidents.

The probability of a single accident is usually determined by historical information on accidents of a similar type and severity. The consequences are estimated by analysis of the quantity of radionuclides likely to be released, potential exposure pathways, potentially affected population, likely weather conditions, and other information.

As an example, the dose risk from a single accident that had a probability of 0.001 (1 chance in 1,000), and would cause a population dose of 22,000 person-rem in a population if it did occur, would be 22 person-rem. If that population was subject to 1,000 similar accident scenarios, the total dose risk would be 22,000 person-rem. Using the conversion factor of 0.0005 latent cancer fatality per person-rem, an analysis would estimate a health and safety risk of 11 latent cancer fatalities from this population dose risk.

The state-specific accident rates (accidents and fatalities per kilometer of vehicle travel) used in the analysis included accident statistics for commercial motor carrier operations for the Interstate Highway System, other U.S. highways, and state highways for each of the 48 contiguous states (DIRS 103455-Saricks and Tompkins 1999, all). The analysis also used average accident and fatality rates for railroads in each state. The data specifically reflect accident and fatality rates that apply to commercial motor carriers and railroads.

Appendix A contains information on the radioactive material contents of shipments. Appendix A, Section A.2.1.5 describes the characteristics of the spent nuclear fuel and high-level radioactive waste that would be shipped. The analysis assumed that the inventory of radioactive materials in shipments would be representative pressurized-water reactor spent nuclear fuel that had been removed from reactors for 15 years. Appendix A describes this inventory. The estimated impacts would be less if the analysis used the characteristics of a typical boiling-water reactor spent nuclear fuel, DOE spent nuclear fuel (including naval spent nuclear fuel, which the analysis assumed would be removed from reactors 5 years before its shipment to the repository), or high-level radioactive waste. Section J.1.2.1.1 describes the casks.

The analysis also used the number of people who potentially would be close enough to transportation routes at the time of an accident to be exposed to radiation or radioactive material released from casks, and the distances these people would be from the accidents. It used the HIGHWAY and INTERLINE computer programs to determine this estimated number of people and their distances from accidents. HIGHWAY and INTERLINE used 1990 Census data for this analysis. In addition, the analysis escalated impacts to account for changes in population from 1990 to 2035 using Bureau of the Census projections. The analysis assumed that the region of influence extended 80 kilometers (50 miles) from an accident involving a release of radioactive material, and 800 meters (0.5 mile) on either side of the route for accidents with no release.

Accident Severity Categories and Conditional Probabilities

For accidents involving release of radioactive material, DIRS 152476-Sprung et al. (2000, pp. 7-73 to 7-76) organizes truck and rail accident scenarios according to estimated severity, likelihood of that severity, and releases that might result. Nineteen scenarios for legal-weight truck and 21 scenarios for rail were postulated. Classification matrices were made for four generic casks and pressurized-water and boiling-water reactor commercial spent nuclear fuel types. Figures J-8a and J-8b show the classification matrices for the cask and fuel used in the analysis of impacts presented in this EIS: steel-depleted uranium-steel casks for truck shipments of pressurized-water reactor fuel and steel-lead-steel casks for rail shipments of pressurized-water reactor fuel. Use of data from DIRS 152476-Sprung et al. (2000, pp. 7-73 to 7-76) for other cask types and for boiling-water reactor spent nuclear fuel would lead to smaller impacts.

Figures J-8a and J-8b have been moved to Volume IV of this EIS.

Accident severity is a function of two variables. The first variable is the mechanical force that occurs in impacts. In the figures, mechanical force is represented by the impact velocity along the vertical axis of the matrix. The second variable is thermal energy, or the heat input to a cask engulfed by fire, also along the horizontal axis. Thermal energy is represented by the midpoint temperature of a cask's lead shield wall following heating, as in a fire.

Because all accident scenarios that would involve casks can be described in these terms, the severity of accidents can be analyzed independently of specific accident sequences. In other words, any sequence of events that results in an accident in which a cask is subjected to mechanical forces, within a certain range of values, and possibly fire is assigned to the accident severity category associated with the applicable ranges for the two parameters. This accident severity scheme enables analysis of a manageable number of accident situations while accounting for all reasonably foreseeable transportation accidents, including accidents with low probabilities but high consequences and those with high probabilities but low consequences. The scheme also encompasses by inference all scenarios that result in a particular outcome.

For the analysis of impacts, a conditional probability was assigned to each accident severity category. Figures J-8a and J-8b show the conditional probabilities developed in DIRS 152476-Sprung et al. (2000, pp. 7-73 to 7-76) for the accident severity matrix. These conditional probabilities were used in the analysis of impacts presented in this appendix. The conditional probabilities are the chances that accidents will involve the mechanical forces and the heat energy in the ranges that apply to the categories. For example, accidents that would fall into Cell 19 in the lower left corner of Figure J-8a, which represents the least severe accident in the matrix, would be likely to make up 99.993 percent of all accidents that would involve truck shipments of casks carrying spent nuclear fuel. The mechanical forces and heat in accidents in this category would not exceed the regulatory design standards for casks. Using the information in the figure, in an accident in this category the safety function of the cask would not be lost and the temperature of the cask would not change. These conditions are within the range of damage that would occur to casks subjected to the hypothetical accident conditions tests that Nuclear Regulatory Commission regulations require a cask to survive (10 CFR Part 71). Accidents in Cell 7 or Cell 12, for example, which would cause considerable damage to a cask, are very severe but very infrequent. Cell 7 accidents would occur an estimated 3 times in each 1 trillion truck accidents, and Cell 12 accidents would occur an estimated 2 times in each 100 trillion truck accidents.

The probabilities shown in each cell of Figures J-8a and J-8b are the conditional probabilities derived from event trees (for example, DIRS 152476-Sprung et al. 2000, p. 7-10) that are assigned to each severity category. These conditional probabilities are the chances that, if an accident occurs, that accident will involve the impact speed and the heat energy in the ranges that apply to the categories. The analysis of accident risks presented in this appendix used the frequency that would be likely for accidents in each of the severity categories. This frequency was determined by multiplying the category's conditional probability by the accident rates for each state's urban, suburban, and rural population zones and by the shipment distances in each of these zones, and then adding the results. The accident rates in the population density zones in each state are distinct and correspond to traffic conditions, including average vehicle speed, traffic density, and other factors, including rural, suburban, or urban location.

Accident Releases

To assess radiological consequences, cask release fractions for each accident severity category for each chemically and physically distinct radioisotope were calculated (DIRS 152476-Sprung et al. 2000, Sections 7.3 and 7.4). The *release fraction* of each isotope is the fraction of that isotope in the cask that could be released from the cask in a given severity of accident. Release fractions vary according to spent nuclear fuel type and the physical/chemical properties of the radioisotopes. Almost all of the radionuclides in spent nuclear fuel are chemically stable and do not react chemically when released. All are physically stable and most are in solid form. Gaseous radionuclides, such as krypton-85, could be released if both the fuel cladding and cask containment boundary were compromised. Volatile radionuclides, like radiocesium iodide, could be released in part, and would also deposit on the inside of the cask, depending on the temperature of the cask.

DIRS 152476-Sprung et al. (2000, p. 7-71) developed release fractions for commercial spent nuclear fuel from both boiling-water and pressurized-water reactors. Figures J-8a and J-8b provide examples of these release fractions. The analysis estimated the amount of radioactive material released from a cask in an accident by multiplying the approximate release fraction by the number of fuel assemblies in a cask (see Table J-3) and the radionuclide activity of a spent nuclear fuel assembly (see Appendix A). To provide perspective, the release fraction for a category 6 accident involving a large rail cask carrying 60 assemblies of spent boiling-water reactor fuel could result in an estimated release of about 48 curies of cesium isotopes. For this analysis, the release fractions developed by DIRS 152476-Sprung et al. (2000, pp. 7-73 to 7-76) were used for commercial pressurized-water and boiling-water reactor fuel. In addition, the analysis used release fractions for spent nuclear fuel from training, research and isotope reactors built by General Atomics (commonly called *TRIGA* spent nuclear fuel), aluminum-based fuel, uranium-carbide fuel, and vitrified high-level radioactive waste.

Accidental Loss of Shielding

Under accident conditions, a reduction in the radiation shielding provided by the spent nuclear fuel cask could occur. An accident where shielding is lost or its effectiveness reduced is often referred to as a loss of shielding accident. Shielding could be lost in high-impact collisions, which could cause lead shielding in a cask to slump towards the point of impact, or in a long-duration, intense fire, which could cause lead shielding to melt and expand. As the lead shielding cooled and solidified, it could shrink and possibly leave voids. Puncture of the cask could result in loss of melted lead. Loss of shielding can occur only in casks that use lead as shielding; it cannot occur in casks that use steel or depleted uranium for shielding.

Using the data presented in Table 8.12 from DIRS 152476-Sprung et al. (2000, pp. 8-47 to 8-50), conditional probabilities, radiation dose rates, and an exposure factor for calculating collective dose were developed for 6 accident severity categories that represent a complete spectrum of loss of shielding accidents (see Table J-19) for 4 cask types. The exposure factors were calculated using RADTRAN 5 assuming that a population from 30 to 800 meters (98 to 2,600 feet) was exposed for 12 hours. Unit risk factors were calculated by multiplying the exposure factor by the accident conditional probability. Category 1 represents accidents where there was no loss of shielding and resulting radiation dose rate and exposure factor are for an undamaged cask. This is the only category applicable to steel or depleted uranium casks. Categories 2 through 6 represent accidents that involve various impact speeds and temperatures. Table J-20 shows the relationship of the 6 accident severity categories for loss of shielding presented here to the 21 rail accident cases and 19 truck accident cases discussed in DIRS 152476-Sprung et al. (2000, pp. 7-73 through 7-76).

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Table J-19. Loss-of-shielding conditional probabilities, radiation dose rates, and exposure factors for four cask types and six accident severity categories.[a]

Cask type	Conditional probability	Radiation dose rate (rem per hour)[b]	Exposure factor (person-rem per person/km^2)[c]
Steel-lead-steel rail			
Category 1	0.9999	1.4×10^{-2}	3.9×10^{-5}
Category 2	6.4×10^{-6}	8.2	7.2×10^{-3}
Category 3	4.9×10^{-5}	2.4	2.0×10^{-3}
Category 4	4.5×10^{-7}	1.3×10^{1}	1.2×10^{-2}
Category 5	2.4×10^{-5}	2.9	2.4×10^{-3}
Category 6	5.2×10^{-9}	2.4×10^{1}	3.0×10^{-2}
Steel-lead-steel truck			
Category 1	0.9999	1.4×10^{-2}	3.9×10^{-5}
Category 2	4.5×10^{-7}	1.3×10^{1}	7.1×10^{-3}
Category 3	4.9×10^{-5}	2.4	8.5×10^{-4}
Category 4	6.4×10^{-6}	8.2	3.5×10^{-3}
Category 5	2.4×10^{-5}	2.9	1.0×10^{-3}
Category 6	5.2×10^{-9}	2.4×10^{1}	2.2×10^{-2}
Monolithic rail			
Category 1	1.0000	1.4×10^{-2}	3.9×10^{-5}
Category 2	0.0	1.4×10^{-2}	3.9×10^{-5}
Category 3	0.0	1.4×10^{-2}	3.9×10^{-5}
Category 4	0.0	1.4×10^{-2}	3.9×10^{-5}
Category 5	0.0	1.4×10^{-2}	3.9×10^{-5}
Category 6	0.0	1.4×10^{-2}	3.9×10^{-5}
Steel-depleted uranium-steel rail			
Category 1	1.0000	1.4×10^{-2}	3.9×10^{-5}
Category 2	0.0	1.4×10^{-2}	3.9×10^{-5}
Category 3	0.0	1.4×10^{-2}	3.9×10^{-5}
Category 4	0.0	1.4×10^{-2}	3.9×10^{-5}
Category 5	0.0	1.4×10^{-2}	3.9×10^{-5}
Category 6	0.0	1.4×10^{-2}	3.9×10^{-5}

a. Source: Calculated by RADTRAN 5.
b. Radiation dose rate at 1 meter from the cask.
c. km^2 = square kilometer; 1 square kilometer = 0.39 square miles or 247.1 acres.

Table J-20. Grouping of accident cases into accident categories.[a]

Accident category	Rail accident cases	Truck accident cases
Category 1	21	19
Category 2	1, 7, 8, 9	2, 10, 11, 12
Category 3	20	18
Category 4	2, 10, 11, 12	1, 7, 8, 9
Category 5	4, 5, 6	4, 5, 6
Category 6	3, 13, 14, 15, 16, 17, 18, 19	3, 13, 14, 15, 16, 17

a. Source: Adapted from DIRS 152476-Sprung et al. (2000, Table 8.12).

The unit risk factor for a category was multiplied by the shipment distance, the number of shipments, the accident rate, and the population density to yield the radiation dose to the exposed population for the category. The radiation doses for all categories were summed to yield the overall radiation dose from all categories of loss of shielding accidents.

Atmospheric Conditions

For the analyses of accident risk and consequences, releases of radioactive materials from casks during and following severe accidents were assumed to be into the air where these materials would be carried by wind. Because it is not possible to predict specific locations where transportation accidents would occur, average U.S. atmospheric conditions were used.

RADTRAN 5, which DOE used in the analysis, contains embedded tables giving the "footprint" of the dispersed plume in curves of constant concentration, called isopleths, for each of the six Pasquill stability classes (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, Chapter 4). These tables incorporate wind speed, downwind distance, area of the footprint, and dilution of the plume. Dispersion of releases from an accident are then modeled by combining these tables to represent national average weather conditions. The RADTRAN 5/database combination was then used in the analysis to calculate an accident *dose risk* incorporating the risk from inhaled and ingested radioactive material, and external radiation from radioactive material deposited on the ground and suspended in the air.

Table J-21 lists the frequency at which atmospheric stability and wind speed conditions occur in the contiguous United States. The data, which are averages for 177 meteorological data collection locations, were used in conjunction with the RADTRAN 5/database to calculate the population (collective) dose risk from any accident, as well as with the RISKIND computer program (DIRS 101483-Yuan et al. 1995, all). RISKIND was used to estimate the consequences of maximum reasonably foreseeable accidents and acts of sabotage.

Table J-21. Frequency of atmospheric and wind speed conditions – U.S. averages.[a]

Atmospheric stability class	Wind speed condition						Total
	WS(1)	WS(2)	WS(3)	WS(4)	WS(5)	WS(6)	
A	0.00667	0.00444	0.00000	0.00000	0.00000	0.00000	0.01111
B	0.02655	0.02550	0.01559	0.00000	0.00000	0.00000	0.06764
C	0.01400	0.02931	0.05724	0.01146	0.00122	0.00028	0.11351
D	0.03329	0.07231	0.15108	0.16790	0.03686	0.01086	0.47230
E	0.00040	0.04989	0.06899	0.00146	0.00016	0.00003	0.12093
F	0.10771	0.08710	0.00110	0.00000	0.00000	0.00000	0.19591
G	0.01713	0.00146	0.00000	0.00000	0.00000	0.00000	0.01859
F+G	0.12485	0.08856	0.00110	0.00000	0.00000	0.00000	0.21451
Totals	*0.20576*	*0.27000*	*0.29401*	*0.18082*	*0.03825*	*0.01117*	*1.00000*
Wind speed (meters per second)[b]	0.89	2.46	4.47	6.93	9.61	12.52	

a. Source: DIRS 104800-CRWMS M&O (1999, p. 40).
b. To convert meters per second to miles per hour, multiply by 2.237.

In calculating estimated values for consequences, RISKIND used the atmospheric stability and wind speed data to analyze the dispersion of radioactive materials in the atmosphere that could follow releases in severe accidents. Using the results of the dispersion analysis, RISKIND calculated values for radiological consequences (population dose and dose to a maximally exposed individual). These results were placed in order from largest to smallest consequence. Following this order, the probabilities of the atmospheric conditions associated with each set of consequences were incorporated to provide a cumulative probability. This procedure was followed to identify the most severe accident consequences that would have a cumulative estimated annual frequency of occurrence of at least 1 in 10 million. The procedure was carried out separately for urban and rural accidents and for neutral and stable atmospheric conditions.

Exposure Pathways

Radiation doses from released radioactive material were calculated for an individual who is postulated to be near the scene of an accident and for populations within 80 kilometers (50 miles) of an accident location. Doses were determined for rural, suburban, and urban population groups. Dose calculations considered a variety of exposure pathways, including inhalation and direct exposure (cloudshine and immersion in a plume of radioactive material) from a passing cloud of contaminants; ingestion from contaminated crops; direct exposure from radioactivity deposited on the ground (groundshine); and inhalation of radioactive particles resuspended by wind from the ground.

Emergency Response, Interdiction, Dose Mitigation, and Evacuation

The RADTRAN 5 computer program that DOE used to estimate radiological risks allows the user to include assumptions about the postaccident remediation of radioactive material contamination of land where people live. The analysis using the program assumed that, after an accident, contaminants would continue to contribute to population dose through three pathways—groundshine, inhalation of resuspended particulates, and, for accidents in rural areas, ingestion of foods produced on the contaminated lands. It also assumed that medical and other interdiction would not occur to reduce concentrations of radionuclides absorbed or deposited in human tissues as a result of accidents.

For a discussion of emergency response to transportation accidents, see Appendix M, Section M.5.

Similarly, the RISKIND (DIRS 101483-Yuan et al. 1995, all) computer program includes assumptions about response, interdiction, dose mitigation, and evacuation for calculating radiological consequences (dose to populations and maximally exposed individuals). In estimating consequences of maximum reasonably foreseeable accidents during the transportation of spent nuclear fuel and high-level radioactive waste to the repository, the analysis assumed the following:

- Populations would continue to live on contaminated land for 1 year.
- There would be no radiological dose to populations from ingestion of contaminated food. Food produced on land contaminated by a maximum reasonably foreseeable accident would be embargoed from consumption.
- Medical and other interdiction would not occur to reduce concentrations of radionuclides absorbed or deposited in human tissues as a result of an accident.

The analysis of a maximum foreseeable loss-of-shielding accident assumed that the vehicle would be stopped at the site of the accident for 12 hours.

Emergency management personnel (first responders) would be between 2 and 10 meters (6.6 and 33 feet) from the vehicle for about an hour to secure the vehicle and keep people away. For about half of this time, the emergency personnel would be exposed to that section of the cask where shielding had been lost.

The analysis of radiological risks to populations and estimates of consequences of maximum reasonably foreseeable accidents did not explicitly address local, difficult-to-evacuate populations such as those in prisons, hospitals, nursing homes, or schools. However, the analysis addressed the potential for accidents to occur in urban areas with high population densities and used the assumptions regarding interdiction, evacuation, and other intervention actions discussed above. These assumptions encompass the consequences and risks that could arise as a result of time to implement measures to mitigate the consequences for some population groups.

Health Risk Conversion Factors

The health risk conversion factors used to estimate expected latent cancer fatalities from radiological exposures are presented in International Commission on Radiological Protection Publication 60 (DIRS 101836-ICRP 1991, p. 22). These factors are 0.0005 latent cancer fatality per person-rem for members of the public and 0.0004 latent cancer fatality per person-rem for workers. For accidents in which individuals would receive doses greater than 20 rem over a short period (high dose/high dose rate), the factors would be 0.0010 latent cancer fatality per rem for a member of the public and 0.0008 latent cancer fatality per rem for workers.

Assessment of Accident Risk

The RADTRAN 5 database (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) was used in calculating risks from transportation of spent nuclear fuel and high-level radioactive waste. The code calculated unit-risk factors (person-rem per person per square kilometer per curie) for the radionuclides of concern in the inventory being shipped (see Appendix A). The unit-risk factors from RADTRAN 5 were combined with conditional accident probabilities, state-specific accident rates, release fractions for each of the six accident severity categories, for each mode of transportation, cask, and spent nuclear fuel or high-level radioactive waste form. For each site traversed, results of this analysis were combined with urban, suburban, and rural distances and population densities, and with the number of shipments. Ingestion dose risks were calculated separately by combining conditional accident probabilities, state-specific accident rates, release fractions for each of the six accident severity collective categories, and rural distances and numbers of shipments for each state with the state-specific food transfer factors. The accident dose risks were estimated in terms of collective radiation dose to the population within 80 kilometers (50 miles).

The analysis first calculated unit risk factors for a shipment. This was done for the three types of population zones in each state and for each accident severity category. The unit risk factors were for one person per square kilometer per kilometer of route traveled. The unit risk factors were multiplied by the population densities (based on 1990 Census data) along the routes. These population densities are modeled as being within 800 meters (0.5 mile) of the routes. The accident dose risk calculation then assumed that the population density in the 800-meter band along the route is the same out to 80 kilometers (50 miles) from the route and multiplies the unit risk factor by this population density, yielding a dose risk in person-rem per kilometer of route for each transportation mode, for each type of impact, and for each state through which a shipment would pass. The resultant dose risks (person-rem per kilometer) for all the applicable accident severity categories were summed for each population zone for each state. Also, for the three types of population zone in a state, the lengths through areas of each type were summed for the route used in the analysis. This yielded route lengths for each population zone in each state. The sum of the route lengths and the sum of the dose risks per kilometer for each population zone were multiplied together. This was repeated for each population zone in each state through which a shipment would pass. The resulting impacts were then multiplied by a scaling factor that is the ratio of the population in a state based on the 1990 Census to projected population in 2035. The results were summed to provide estimates of the accident dose risk (in person-rem) for a shipment.

Estimating Consequences of Maximum Reasonably Foreseeable Accident Scenarios

In addition to analyzing the radiological and nonradiological risks that would result from the transportation of spent nuclear fuel and high-level radioactive waste to the repository, DOE assessed the consequences of maximum reasonably foreseeable accidents using the analysis from DIRS 152476-Sprung et al. (2000, pp. 7-30 to 7-70) for releases of material from a spent nuclear fuel cask during an accident. This analysis provided information about the magnitude of impacts that could result from the most severe accident that could reasonably be expected to occur, although it could be highly unlikely. DOE concluded that, as a practical matter, events with a probability less than 1×10^{-7} (1 chance in 10 million) per year rarely need to be examined (DIRS 104601-DOE 1993, p. 28). This would be equivalent to about once in the course of 15 billion legal-weight truck shipments. For perspective, an accident this severe in commercial truck transportation would occur about once in 50 years on U.S. highways. Thus, the analysis of maximum reasonably foreseeable accidents postulated to occur during the transportation of spent nuclear fuel and high-level radioactive waste evaluated only consequences for accidents with a probability greater than 1×10^{-7} per year. The consequences were determined for atmospheric conditions that could prevail during accidents and for physical and biological pathways that would lead to exposure of members of the public and workers to radioactive materials and ionizing radiation. The analysis used the RISKIND code (DIRS 101483-Yuan et al. 1995, all) to estimate doses for individuals and populations. In addition to the accidents with a probability greater than 1×10^{-7} per year, the analysis estimated the consequences from all accident severity categories presented in DIRS 152476-Sprung et al. (2000, pp. 7-73 and 7-76) for a steel-depleted uranium-steel truck cask and a steel-lead-steel rail cask. The following list describes those severity categories:

Rail Accident Descriptions

- *Case 20:* Case 20 is a long-duration (many hours), high-temperature fire that would engulf a cask. Conditions reported in the Baltimore Sun Times for the Baltimore Tunnel Fire (DIRS 156753-Ettlin 2001, all; DIRS 156754-Rascovar 2001, all), which occurred in July 2001—a fire of 820ºC (1,500ºF) that burned for up to 5 days—would be similar to the conditions for a Case 20 accident.

- *Cases 19, 18, 17, and 16:* Case 19 is a high-speed (more than 120 miles per hour) impact into a hard object such as a train locomotive severe enough to cause failure of cask seals and puncture through the cask's shield wall. The impact would be followed by a very long duration (many hours), high-temperature engulfing fire. Case 18, Case 17, and Case 16 are accidents that would also involve very long duration fires, failures of cask seals, and puncture of cask walls. However, these accidents would be progressively less severe in terms of impact speeds. The impact speeds range from 90 to 120 miles for Case 18, 60 to 90 miles per hour for Case 17, and 30 to 60 miles per hour for Case 16.

- *Cases 15, 12, 9, and 6:* Case 15 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by a long duration (many hours), high-temperature engulfing fire. Case 12, Case 9, and Case 6 are also accidents that would involve long duration fires, and failures of cask seals. However, these accidents would be progressively less severe in terms of impact speeds ranging from 90 to 120 miles for Case 12, 60 to 90 miles per hour for Case 9, and 30 to 60 miles per hour for Case 6.

- *Cases 14, 11, 8, and 5:* Case 14 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by a high-temperature engulfing fire that burned for hours. Case 11, Case 8, and Case 5 are also accidents that would involve fires that would burn for hours, and failures of cask seals. However, these accidents would be progressively less severe in terms of impact speeds ranging from 90 to 120 miles for Case 11, 60 to 90 miles per hour for Case 8, and 30 to 60 miles per hour for Case 5.

- *Cases 13, 10, 7, and 4:* Case 13 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by an engulfing fire lasting more than ½ hour up to a few hours. Case 10, Case 7, and Case 4 are accidents that would involve long duration fires, and failures of cask seals. However, these accidents are progressively less severe in terms of impact speeds ranging from 90 to 120 miles for Case 10, 60 to 90 miles per hour for Case 7, and 30 to 60 miles per hour for Case 4. An accident involving the impact of a jet engine from a passenger aircraft on a rail cask would be no more severe than a Case 4 accident (DIRS 157210-BSC 2001, all).

- *Cases 3, 2, and 1:* Case 3 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals—no fire. Case 2 and Case 1 are accidents that would also not involve fire but would have progressively lower impact speeds - 90 to 120 miles for Case 2 and 60 to 90 miles per hour for Case 1.

Truck Accident Descriptions

- *Case 18:* Case 18 is a long-duration (many hours), high-temperature fire that would engulf a cask. Conditions reported in the Baltimore Sun Times for the Baltimore Tunnel Fire (DIRS 156753-Ettlin 2001, all; DIRS 156754-Rascovar 2001, all), which occurred in July 2001—a fire of 820ºC (1,500ºF) that burned for up to 5 days—would be similar to the conditions for a Case 18 accident.

- *Cases 17, 16, 15, and 14:* Case 17 is a high-speed (more than 120 miles per hour) impact into a hard object such as a train locomotive severe enough to cause failure of cask seals and puncture through the cask's shield wall. The impact would be followed by a very long duration (many hours), high-temperature engulfing fire. Case 16, Case 15, and LST 14 are accidents that would also involve very long duration fires, failures of cask seals, and puncture of cask walls. However, these accidents would be progressively less severe in terms of impact speeds. The impact speeds range from 90 to 120 miles for Case 16, 60 to 90 miles per hour for Case 15, and 30 to 60 miles per hour for Case 14.

- *Cases 13, 10, 7, and 4:* Case 13 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by a long duration (many hours), high-temperature engulfing fire. Case 10, Case 7, and Case 4 are also accidents that would involve long duration fires, and failures of cask seals. However, these accidents would be progressively less severe in terms of impact speeds ranging from 90 to 120 miles for Case 10, 60 to 90 miles per hour for Case 7, and 30 to 60 miles per hour for Case 4.

- *Cases 12, 9, 6, and 3:* Case 12 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by a high-temperature engulfing fire that burned for hours. Case 9, Case 6, and Case 3 are also accidents that would involve fires that would burn for hours, and failures of cask seals. However, these accidents would be progressively less severe in terms of impact speeds ranging from 90 to 120 miles for Case 9, 60 to 90 miles per hour for Case 6, and 30 to 60 miles per hour for Case 3.

- *Cases 11, 8, 5, and 2:* Case 11 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by an engulfing fire lasting more than ½ hour up to a few hours. Case 8, Case 5, and Case 2 are accidents that would involve long duration fires, and failures of cask seals. However, these accidents are progressively less severe in terms of impact speeds ranging from 90 to 120 miles for Case 8, 60 to 90 miles per hour for Case 5, and 30 to 60 miles per hour for Case 2. An accident involving the impact of a jet engine from a passenger aircraft on a truck cask would be no more severe than any Case 11 accident (DIRS 157210-BSC 2001, all).

- *Case 1:* Case 1 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals—no fire.

The analysis assumed maximum reasonably foreseeable accident scenarios could occur anywhere, either in rural or urbanized areas. The probability of such an accident would depend on the amount of exposure to the transportation accident environment. In this case, exposure would be the product of the cumulative shipment distance and the applicable accident rates. However, because of large differences in exposure, principally because of the large differences in the distances traveled in the two types of population areas, a severe accident scenario that might be reasonably foreseeable in a rural area might not be reasonably foreseeable in an urbanized area. Thus, a reasonably foreseeable accident postulated to occur in a rural area (most travel would occur in rural areas), under meteorological conditions that would be exceeded (resulting in greater consequences) only 5 percent of the time, might not be reasonably foreseeable in an urbanized area where shipments would travel relatively few kilometers. Table J-22 lists the probabilities and consequences of severe rail cask accidents during national transportation based on the analysis of releases from spent fuel casks presented in DIRS 152476-Sprung et al. (2000, pp. 7-75 to 7-76) for urban

Table J-22. Frequency and consequence of rail accidents.[a]

Rail cask					
Case	Expected frequency	Total exposure (person-rem)	Case	Expected frequency	Total exposure (person-rem)
Urban Area - Stability Class F			Rural Area - Stability Class F		
19	7.67×10^{-19}	254,377	19	4.71×10^{-18}	419
15	7.67×10^{-16}	254,377	15	4.71×10^{-15}	419
14	5.77×10^{-15}	242,817	14	3.54×10^{-14}	400
13	2.07×10^{-13}	230,214	13	1.27×10^{-12}	379
16	2.32×10^{-12}	220,788	16	1.43×10^{-11}	364
3	2.51×10^{-11}	219,698	3	1.54×10^{-10}	361
18	9.74×10^{-17}	173,447	18	5.99×10^{-16}	285
12	9.74×10^{-14}	173,447	12	5.99×10^{-13}	285
11	7.34×10^{-13}	171,358	11	4.51×10^{-12}	282
6	6.16×10^{-10}	159,807	6	3.78×10^{-9}	264
10	2.62×10^{-11}	149,279	10	1.61×10^{-10}	246
2	3.18×10^{-9}	149,266	2	1.95×10^{-8}	245
17	1.41×10^{-15}	112,468	17	8.63×10^{-15}	185
9	1.41×10^{-12}	81,049	9	8.63×10^{-12}	134
20	2.75×10^{-7}	9,893	20	1.69×10^{-6}	16.3
8	1.05×10^{-11}	3,416	8	6.47×10^{-11}	5.63
7	3.79×10^{-10}	3,060	7	2.33×10^{-9}	5.04
1	4.59×10^{-8}	2,933	1	2.82×10^{-7}	4.83
5	4.61×10^{-9}	1,745	5	2.83×10^{-8}	2.88
4	1.66×10^{-7}	1,346	4	1.02×10^{-6}	2.22

a. Source: DIRS 152476-Sprung et al. (2000, p. 7-75).

area and rural area population and stability class F weather conditions. Stability class D consequences were analyzed but, because the consequences are smaller than those of class F stability conditions, they are not presented. Similarly, Table J-23 lists the probabilities and consequences of severe truck accidents for stability class F conditions.

For the mostly rail scenario, legal-weight truck accidents would not be reasonably foreseeable. For rail accidents, the severity case, which is reasonably foreseeable and would have the greatest consequences, is Case 20 with an expected frequency of 2.8×10^{-7} and consequences of 9,900 person-rem.

For the mostly legal-weight truck scenario, in which only naval spent nuclear fuel would be shipped by rail, the likelihood would be less than 1×10^{-7} per year for the most severe rail accident to occur in an urbanized area. Thus, the highest severity rail accidents would only be reasonably foreseeable in rural areas under average (50-percent) meteorological conditions (probability greater than 1 in 10 million per year). For truck accidents in urban areas, the severity case, which is reasonably foreseeable and has the greatest consequences, is Case 18 with an expected frequency of 2.3×10^{-7} and consequences of 1,100 person-rem.

The analysis of maximum reasonably foreseeable accidents evaluated all the accidents for steel-depleted uranium-steel truck and steel-lead-steel rail casks from DIRS 152476-Sprung et al. (2000, pp. 7-73 and 7-76). However, only accidents from Tables J-22 and J-23 that have an expected frequency greater than 1×10^{-7} would be reasonably foreseeable.

Table J-24 summarizes the accidents with the greatest consequences that would be reasonably foreseeable. Although stability class D accidents are reasonably foreseeable, the consequences from stability class F accidents would be greater as listed in Table J-24.

Table J-23. Frequency and consequence of truck accidents.[a]

Truck cask					
Case	Expected frequency	Total exposure (person-rem)	Case	Expected frequency	Total exposure (person-rem)
Urban Area - Stability Class F			Rural Area - Stability Class F		
14	2.8×10^{-12}	36,798	14	1.6×10^{-11}	60.7
15	1.3×10^{-16}	18,919	15	7.6×10^{-16}	31.1
4	2.8×10^{-9}	8,484	4	1.6×10^{-8}	14
7	1.3×10^{-13}	5,203	7	7.6×10^{-13}	8.57
12	9.8×10^{-16}	1,251	12	5.5×10^{-15}	2.07
9	7.7×10^{-14}	1,251	9	4.4×10^{-13}	2.07
11	6.0×10^{-12}	1,146	11	3.4×10^{-11}	1.88
8	4.7×10^{-10}	1,146	8	2.7×10^{-9}	1.88
1	6.2×10^{-10}	1,125	1	3.5×10^{-9}	1.85
18	2.3×10^{-7}	1,083	18	1.3×10^{-6}	1.79
6	3.7×10^{-12}	723	6	2.1×10^{-11}	1.19
5	2.0×10^{-8}	581	5	1.1×10^{-7}	0.92
3	1.1×10^{-8}	291	3	6.4×10^{-8}	0.48
2	2.5×10^{-6}	225	2	1.4×10^{-5}	0.37
17	0	N/A[b]	17	0	N/A[b]
16	0	N/A	16	0	N/A
13	0	N/A	13	0	N/A
10	0	N/A	10	0	N/A

a. Source: DIRS 152476-Sprung et al. (2000, p. 7-74).
b. N/A = not applicable, because probability is zero.

Table J-24. Consequences (person-rem) of maximum reasonably foreseeable accidents in national transportation.[a]

Case	Urban (person-rem)	Rural (person-rem)	MEI (rem)[b]
Rail (Case 20)	9,893	16	29
Truck (Case 18)	1,083	2	3

a. All accidents are modeled in with stability class F conditions.
b. MEI = maximally exposed individual.

The analysis of consequences of maximum reasonably foreseeable accidents used data from the 1990 census escalated to 2035 to estimate the size of populations in urbanized areas that could receive exposures to radioactive materials. The analysis used estimated populations in successive 8-kilometer (5-mile)-wide annular rings around the centers of the 21 large urbanized areas (cities and metropolitan areas) in the continental United States (DIRS 104800-CRWMS M&O 1999, p. 22).

The average population for each ring was used to form a population distribution for use in the analysis. To be conservative in estimating consequences, the analysis assumed that accidents in urbanized areas would occur at the center of the population zone, where the population density would be greatest. This assumption resulted in conservative estimates of collective dose to exposed populations.

J.1.4.2.2 *Methods and Approach for Analysis of Nonradiological Impacts of Transportation Accidents*

Nonradiological accident risks are risks of traffic fatalities. Traffic fatality rates are reported by state and Federal transportation departments as fatalities per highway vehicle- or train-kilometer traveled. The fatalities are caused by physical trauma in accidents. For nonradiological accident risks estimated in this

EIS for legal-weight truck transportation, accident fatality risks were based on state-level fatality rates for Interstate Highways (DIRS 103455-Saricks and Tompkins 1999, all). Accident fatality risks for rail transportation were also calculated using state-specific rates (DIRS 103455-Saricks and Tompkins 1999, all). Section J.2.2 discusses methods and data used to analyze accidents for barge transportation.

For truck transportation, the rates in DIRS 103455-Saricks and Tompkins (1999, Table 4) are specifically for heavy combination trucks involved in interstate commerce. Heavy combination trucks are multiaxle tractor-trailer trucks having a tractor and one to three freight trailers connected to each other. This kind of truck with a single trailer would be used to ship spent nuclear fuel and high-level radioactive waste. Truck accident rates were determined for each state based on statistics compiled by the U.S. Department of Transportation Office of Motor Carriers for 1994 through 1996. The report presents accident involvement and fatality counts, estimated kilometers of travel by state, and the corresponding average accident involvement, fatality, and injury rates for the 3 years investigated. Fatalities include crew members and all others attributed to accidents. Although escort vehicles would not be heavy combination trucks, the fatality rate data used for truck shipments of loaded and empty spent fuel casks were also used to estimate fatalities from accidents that would involve escort vehicles.

Rail accident rates were computed and presented similarly to truck accident rates, but a railcar is the unit of haulage. The state-specific rail accident involvement and fatality rates are based on statistics compiled by the Federal Railroad Administration for 1994 through 1996. Rail accident rates include both mainline accidents and those occurring in railyards. The per-railcar rate in DIRS 103455-Saricks and Tompkins (1999, Table 6) was multiplied by 4.2, the average number of railcars involved in an accident.

The accident rates used to estimate traffic fatalities were computed using data for all interstate shipments, independent of the cargoes. Shippers and carriers of radioactive material generally have a higher-than-average awareness of transport risk and prepare cargoes and drivers accordingly (DIRS 101920-Saricks and Kvitek 1994, all). These effects were not given credit in the assessment.

J.1.4.2.3 *Data Used To Estimate Incident Rates for Rail and Motor Carrier Accidents*

In analyzing potential impacts of transporting spent nuclear fuel and high-level radioactive waste, DOE considered both incident-free transportation and transportation accidents. Potential incident-free transportation impacts would include those caused by exposing the public and workers to low levels of radiation and other hazards associated with the normal movement of spent nuclear fuel and high-level radioactive waste by truck, rail, or barge. Impacts from accidents would be those that could result from exposing the public and workers to radiation, as well as vehicle-related fatalities.

In its analysis of impacts from transportation accidents, DOE relied on data collected by the U.S. Department of Transportation and others (for example, the American Petroleum Institute) to develop estimates of accident likelihood and their ranges of severity (DIRS 101828-Fischer et al. 1987, pp. 7-25 and 7-26). Using these data, the analysis estimated that as many as 66 accidents could occur over 24 years in the course of shipping spent nuclear fuel to the repository by legal-weight trucks; 8 rail accidents that involved a railcar carrying a cask could occur if most shipments were by rail; and no accidents would be likely for the limited use of barges.

Furthermore, in using data collected by the U.S. Department of Transportation, the analysis considered the range of accidents, from slightly more than “fender benders” to high-speed crashes, that the DOE carrier would have to report in accordance with the requirements of U.S. Department of Transportation regulations. The accidents that could occur would be unlikely to be severe enough to affect the integrity of the shipping casks.

Main Index
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The following paragraphs discuss reporting and definitions for transportation accidents and the relationships of these to data used in analyzing transportation impacts in this EIS.

J.1.4.2.3.1 Transportation Accident Reporting and Definitions. In the United States, the reporting of transportation accidents and incidents involving trucks, railroads, and barges follows requirements specified in various Federal and state regulations.

Motor Carrier Accident Reporting and Definitions

Regulations generally require the reporting of motor carrier accidents (regardless of the cargo being carried) if there are injuries, fatalities, or property damage. These regulations have evolved through the years, mostly in response to increasing values of transportation equipment and commodities. For example, the Federal requirements in the following text box establish a functional threshold for damage to vehicles rather than a value-of-damage threshold, which was used until the 1980s. Nonetheless, many states continue to use value thresholds (for example, Ohio uses $500) for vehicle damage when documenting reportable accidents.

Until March 4, 1993, Federal regulations (49 CFR Part 394) required motor carriers to submit accident reports to the Federal Highway Administration Motor Carrier Management Information System using the so-called “50-T” reporting format. The master file compiled from the data on these reports in the Federal Highway Administration Office of Motor Carriers was the basis of accident, fatality, and injury rates developed for the 1994 study of transportation accident rates (DIRS 101920-Saricks and Kvitek 1994, all).

The Final Rule (58 *FR* 6726; February 2, 1993) modified the carrier reporting requirement; rather than submitting reports, carriers now must maintain a register of accidents that meet the definition of an accident for 1 year after such an accident occurs. Carriers must make the contents of such a register available to Federal Highway Administration agents investigating specific accidents. They must also give “…all reasonable assistance in the investigation of any accident including providing a full, true, and correct answer to any question of inquiry” to determine if hazardous materials other than spilled fuel from the fuel tanks were released, and to furnish copies of all state-required accident reports (49 CFR 390.15). The reason for this rule change was the emergence of an automated State accident reporting system compiled from law enforcement accident reports that, pursuant to provisions of the Intermodal Surface Transportation Efficiency Act of 1991 (Public Law 102-240, 105 Stat. 1914), was established under the Motor Carrier Safety Assistance Program.

Under Section 408 of Title IV of the Motor Carrier Act of 1991 (Public Law 102-240, 105 Stat. 2140), a component of the Intermodal Surface Transportation Efficiency Act, the Secretary of Transportation is authorized to make grants to states to help them achieve uniform implementation of the police reporting system for truck and bus accidents recommended by the National Governors Association. Under this system, called SAFETYNET, accident data records generated by each state follow identical formatting and content instructions. They are entered in a Federally maintained SAFETYNET database on approximately a weekly basis. The SAFETYNET database, in turn, is compiled and managed as part of the Motor Carrier Management Information System.

Because DIRS 152476-Sprung et al. (2000, all) is the fundamental source for data that describes the severity of transportation accidents used in this EIS, the relative constancy of the definition of *accident* is important in establishing confidence in estimated impact results. Thus, although the transportation environment has changed over the 40 years of data collection, the constancy of the definition of *accident* tends to provide confidence that the distribution of severity for reported accidents has remained relatively the same. That is, low-consequence, fender-bender accidents are the most common, high-consequence, highly energetic accidents are rare, and the proportions of these have remained roughly the same.

COMMERCIAL MOTOR VEHICLE ACCIDENT
(49 CFR 390.5)

An occurrence involving a commercial motor vehicle operating on a public road in interstate or intrastate commerce that results in:

- A fatality
- Bodily injury to a person who, as a result of the injury, immediately receives medical treatment away from the scene of the accident
- One or more motor vehicles incurring disabling damage as a result of the accident, requiring the motor vehicle to be transported away from the scene by a tow truck or other motor vehicle

The term accident does not include:

- An occurrence involving only boarding and alighting from a stationary motor vehicle
- An occurrence involving only the loading or unloading of cargo
- An occurrence in the course of the operation of a passenger car or a multipurpose passenger vehicle by a motor carrier and is not transporting passengers for hire or hazardous materials of a type and quantity that require the motor vehicle to be marked or placarded in accordance with 49 CFR 177, Subpart 823

Changes in the transportation environment, such as changes in speed limits and safety technology, tend to change the accident rate (accidents per vehicle-kilometer of travel). Overall, however, given that the definition of *accident* does not change, such changes do not greatly affect the distribution of accident severities. For example, recent increases in speed limits from 105 to 121 kilometers (65 to 75 miles) per hour represent about a 25-percent increase in the maximum mechanical energy of vehicles. Other information aside, this increase could lead to the conclusion that the resulting distribution of accidents would show an increase for the most severe accidents in comparison to minor accidents. However, the speed limit increases do not represent a corresponding increase in actual traffic speeds, and would be unlikely to change the distribution of velocities and, thus, mechanical energies, of severe accidents from those reported in DIRS 152476-Sprung et al. (2000, all), which ranged to faster than 193 kilometers (120 miles) per hour.

Rail Carrier Accident Reporting and Definitions

As with regulations governing the reporting of motor carrier accidents, Federal Railroad Administration regulations generally require the reporting of accidents if there are injuries, fatalities, or property damage. These regulations have evolved through the years, mostly in response to increasing values of transportation equipment and commodities. For example, the Federal requirements in the following text box establish a value-based reporting threshold for damage to vehicles; the value has been indexed to inflation since 1975.

Rail carriers covered by these requirements must fulfill several bookkeeping tasks. The Federal Railroad Administration requires the submittal of a monthly status report, even if there were no reportable events during the period. This report must include accidents and incidents, and certain types of incidents require immediate telephone notification. Logs of reportable injuries and on-track incidents must be maintained by the railroads on which they occur, and a listing of such events must be posted and made available to employees and to the Federal Railroad Administration, along with required records and reports, on request. The data entries extracted from the reporting format are consolidated into an accident/incident database that separates reportable *accidents* from grade-crossing *incidents*. These are processed annually into event, fatality, and injury count tables in the Federal Railroad Administration's *Accident/Incident Bulletin* (DIRS 103455-Saricks and Tompkins 1999, all), which the Office of Safety publishes on the Internet (*safetydata.fra.dot.gov/officeofsafety*).

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RAILROAD ACCIDENT/INCIDENT
(49 CFR 225.11)

- An impact between railroad on-track equipment and an automobile, bus, truck, motorcycle, bicycle, farm vehicle or pedestrian at a highway-rail grade crossing
- A collision, derailment, fire, explosion, act of God, or other event involving operation of railroad on-track equipment (standing or moving) that results in reportable damages greater than the current reporting threshold to railroad on-track equipment, signals, track, track structures, and roadbed
- An event arising from the operation of a railroad which results in:
  - Death to any person
  - Injury to any person that requires medical treatment
  - Injury to a railroad employee that results in:
    - A day away from work
    - Restricted work activity or job transfer
    - Loss of consciousness
    - Occupational illness

In contrast to the regulations for motor carriers discussed above, the Federal Railroad Administration regulations cited above call for the reporting of accidents and incidents. The Administration defines an *accident* as “an event involving on-track railroad equipment that results in damage to the railroad on-track equipment, signals, track, or track structure, and roadbed at or exceeding the dollar damage threshold” (49 CFR 225.11). Train *incidents* are defined as “events involving on-track railroad equipment [and non-train incidents arising from the operation of a railroad] that result in the reportable death and/or injury or illness of one or more persons, but do not result in damage at or beyond the damage threshold” (49 CFR 225.11). Because damage to casks containing spent nuclear fuel will necessarily involve severe accidents (hence, substantial damage), DIRS 152476-Sprung et al. (2000, all) used only train accidents to form the basis for developing the conditional probabilities of accident severities.

As with motor carrier operations, the constancy of the definition of a train accident is important in establishing confidence in the impact. For rail accidents the transportation environment has not changed dramatically over the years of data collection, and the definition of *accident* has remained essentially unchanged (with adjustments for inflation). The constancy of the definition provides confidence that the distribution of severity for reported accidents has remained relatively the same—low-consequence, limited-damage accidents are the most common and high-consequence, highly energetic accidents are rare, and their proportions have remained about the same. Changes in the rail transportation environment, as in safety and operations technology (for example, shelf-type couplers and tankcar head protection), have resulted in lower accident rates (per railcar-kilometer of travel) and, in some cases, less severe accidents. However, because the definition of *accident* has not changed appreciably, the changes that have occurred are not the kind that would greatly affect the relative proportions of minor and severe accidents.

Reporting and Definitions for Marine Casualties and Incidents

As with the regulations governing the reporting of motor carrier and rail accidents, U.S. law (46 U.S.C. 6101 to 6103) requires operators to report marine casualties and incidents if there are injuries, fatalities, or property damage. In addition, the law requires the reporting of significant harm to the environment.

MARINE CASUALTY AND INCIDENT
(46 U.S.C. 6101 to 6103)

Criteria have been established for the required reporting (by vessel operators and owners) of marine casualties and incidents involving all United States flag vessels occurring anywhere in the world and any foreign flag vessel operating on waters subject to the jurisdiction of the United States. An incident must be reported within five days if it results in:

- The death of an individual
- Serious injury to an individual
- “Material” loss of property (threshold not specified; previously was $25,000)
- Material damage affecting the seaworthiness or efficiency of the vessel
- Significant harm to the environment

The states collect casualty data for incidents occurring in navigable waterways within their borders, and there is a uniform state marine casualty reporting system for transmitting these reports to Federal jurisdiction (the U.S. Coast Guard). Coast Guard Headquarters receives quarterly extracts of the Marine Safety Information System developed from these sources. This system is a network database into which Coast Guard investigators enter cases at each marine safety unit. The analysis uses a Relational Database Management System. The Coast Guard Office of Investigations and Analysis compiles and processes the casualty reports into the formats and partitioned data sets that comprise the Marine Safety Information System database, which includes maritime accidents, fatalities, injuries, and pollution spills dating to 1941 (however, the file is complete only from about 1991 to the present).

Hazardous Material Transportation Accident and Incident Reporting and Definitions

Radioactive material is a subset of the more general term *hazardous material*, which includes commodities such as gasoline and chemical products. The U.S. Department of Transportation Office of Hazardous Materials estimates that there are more than 800,000 hazardous materials shipments per day, of which about 7,700 shipments contain radioactive materials.

Hazardous materials transportation regulations (49 CFR 171) contain no distinction between an *accident* and an *incident*, and *incident* is the term used to describe situations that must be reported. Hazardous materials regulations (49 CFR 171.15) require the reporting of incidents if:

- A person is killed
- A person receives injuries requiring hospitalization
- The estimated property damage is greater than $50,000
- An evacuation of the public occurs lasting one or more hours
- One or more major transportation arteries are closed or shutdown for one or more hours
- The operational flight pattern or routine of an aircraft is altered
- Fire, breakage, spillage, or suspected radioactive contamination occurs involving shipment of radioactive material
- Fire, breakage, spillage, or suspected contamination occurs involving shipment of infectious agents

- There has been a release of a marine pollutant in a quantity exceeding 450 liters (about 120 gallons) for liquids or 400 kilograms (about 880 pounds) for solids

- There is a situation that, in the judgement of the carrier, should be reported to the U.S. Department of Transportation even though it does not meet the above criteria

These criteria apply to loading, unloading, and temporary storage, as well as to transportation. The criteria involving infectious agents or aircraft are unlikely to be used for spent nuclear fuel or high-level radioactive waste shipments. Based on these criteria, reportable motor vehicle and rail transportation situations are far more exclusionary than hazardous material situations.

Carriers (not law enforcement officials) are required to report hazardous materials incidents to the U.S. Department of Transportation. These reports are compiled in the Hazardous Materials Incident Report database. In addition, U.S. Nuclear Regulatory Commission regulations (10 CFR 20.2201, 20.2202, 20.2203) require the reporting of a loss of radioactive materials, exposure to radiation, or release of radioactive materials.

Sandia National Laboratories maintains the Radioactive Materials Incident Report database, which contains incident reports from the Hazardous Materials Incident Report database that involve radioactive material. In addition, the Radioactive Materials Incident Report database contains data from the U.S. Nuclear Regulatory Commission, state radiation control offices, the DOE Unusual Occurrence Report database, and media coverage of radioactive materials transportation incidents. DIRS 101802-DOE (1995, Volume 1, Appendix I, pp. I-117) and DIRS 102172-McClure and Fagan (1998, all) discuss historic incidents involving spent nuclear fuel that are reported in the Radioactive Materials Incident Report database as well as incidents that took place prior to the existence of this database. The database characterizes incidents in three categories: transportation accidents, handling accidents, and reported incidents. However, the definitions of these categories are not consistent with the definitions used in other U.S. Department of Transportation databases. For example, from 1971 through 1998, the Radioactive Materials Incident Report database lists one transportation accident involving a loaded rail shipment of spent nuclear fuel. However, based on current Federal Railroad Administration reporting requirements, this occurrence probably would be listed as a grade-crossing incident, not an accident. For this reason and because of the small number of occurrences in the database involving spent nuclear fuel, the EIS analysis did not use the Radioactive Materials Incident Report database to estimate transportation accident rates.

J.1.4.2.3.2 Accident Rates for Transportation by Heavy-Combination Truck, Railcar, and Barge in the United States. DIRS 103455-Saricks and Tompkins (1999, all) developed estimates of accident rates for heavy-combination trucks, railcars, and barges based on data available for 1994 through 1996. The estimates provide an update for accident rates published in 1994 (DIRS 101920-Saricks and Kvitek 1994, all) that reflected rates from almost a decade earlier.

Rates for Accidents in Interstate Commerce for Heavy-Combination Trucks

DIRS 103455-Saricks and Tompkins (1999, all) developed basic descriptive statistics for state-specific rates of accidents involving interstate-registered combination trucks for 1994, 1995, and 1996. The accident rate over all road types for 1994 was 2.98×10^{-7} accident per truck-kilometer (DIRS 103455-Saricks and Tompkins 1999, Table 3a); for 1995 it was 2.97×10^{-7} accident per truck-kilometer (DIRS 103455-Saricks and Tompkins 1999, Table 3b); and for 1996 it was 3.46×10^{-7} accident per truck-kilometer (DIRS 103455-Saricks and Tompkins 1999, Table 3c). The composite mean from 1994 through 1996 was 3.21×10^{-7} accident per truck-kilometer.

During the 24 years of the Proposed Action, the *mostly legal-weight truck* national transportation scenario would involve about 53,000 truck shipments of spent nuclear fuel and high-level radioactive waste.

Based on the data in DIRS 103455-Saricks and Tompkins (1999, Table 4), the transportation analysis estimated that those shipments could involve as many as 66 accidents. During the same period, the *mostly rail* scenario would involve about 1,100 truck shipments, and the analysis estimated that as many as one truck accident could occur during these shipments. More than 99.99 percent of these accidents would not generate forces capable of causing functional damage to the casks, and would have no radiological consequences. A small fraction of the accidents could generate forces capable of damaging the cask.

Rates for Freight Railcar Accidents

Results for accident rates for freight railcar shipments from DIRS 103455-Saricks and Tompkins (1999, all), show that domestic rail freight accidents, fatalities, and injuries on Class 1 and 2 railroads have remained stable or declined slightly since the late 1980s. Based on data from 1994 through 1996, these rates are 5.39×10^{-8}, 8.64×10^{-8}, and 1.05×10^{-8} per railcar-kilometer, respectively (DIRS 103455-Saricks and Tompkins 1999, Table 6). This conclusion is based on applying denominators that do *not* include train and car kilometers for intermodal shipments (containers and trailers-on-flatcar) not loaded by the carriers themselves. Thus, the actual denominators are probably higher and the rates consequently lower, by about 20 percent.

During the 24 years of the Proposed Action, the *mostly rail* national transportation scenario would involve as many as 10,000 rail shipments of spent nuclear fuel and high-level radioactive waste. Based on the data in DIRS 103455-Saricks and Tompkins (1999, Table 6), the analysis estimated that these shipments could involve eight accidents. More than 99.99 percent of these accidents would not generate forces capable of causing functional damage to the cask; these accidents would have no radiological consequences. A small fraction of the accidents could generate forces capable of damaging the cask. For the *mostly legal-weight truck* scenario, rail accidents would be unlikely during the 300 railcar shipments of naval spent nuclear fuel.

Rates for Barge Accidents

Waterway results show a general improvement over mid-1980s rates. The respective rates for 450-metric-ton (500-ton) shipments for waters internal to the coast (rivers, lakes, canals, etc.) for accident and incident involvements and fatalities were 1.68×10^{-6} and 8.76×10^{-9} per shipment-kilometer, respectively (DIRS 103455-Saricks and Tompkins 1999, Table 8b). Rates for lake shipping were lower—2.58×10^{-7} and 0 per shipment-kilometer, for accidents and incidents and for fatalities, respectively. Coastal casualty involvement rates have risen in comparison to the data recorded about 10 years ago, and are comparable to rates for internal waters—5.29×10^{-7} and 8.76×10^{-9} per shipment-kilometer (DIRS 103455-Saricks and Tompkins 1999, Table 9b).

During the 24 years of the Proposed Action, the *mostly rail* national transportation scenario could involve the use of barges to ship spent nuclear fuel from 17 commercial sites. Based on the data in DIRS 103455-Saricks and Tompkins (1999, all), the analysis estimated that less than one accident could occur during such shipments. A barge accident severe enough to cause measurable damage to a shipping cask would be highly unlikely.

Rates for Safe Secure Trailer Accidents

DOE uses safe secure trailers to transport hazardous cargoes in the continental United States. The criteria used for reporting accidents involving these trailers are damage in excess of $500, a fire, a fatality, or damage sufficient for the trailer to be towed. From 1975 through 1998, 14 accidents involved safe secure trailers over about 54 million kilometers (about 34 million miles) of travel, which yields a rate of 2.6×10^{-7} accident per kilometer (4.2×10^{-7} per mile). This rate is comparable to the rate estimated by DIRS 103455-Saricks and Tompkins (1999, Table 4) for heavy combination trucks, 3.2×10^{-7} accident per kilometer (5.1×10^{-7} per mile).

J.1.4.2.3.3 Accident Data Provided by the States of Nevada, California, South Carolina, Illinois, and Nebraska. In May 1998, DOE requested the 48 contiguous states to provide truck and rail transportation accident data for use in this EIS. Five states responded – Nevada, California, Illinois, Nebraska, and South Carolina (DIRS 104728-Denison 1998, all; DIRS 103709-Caltrans 1997, all; DIRS 104801-Wort 1998, all; DIRS 104783-Kohles 1998, all; DIRS 103725-SCDPS 1997, all). No states provided rail information.

- *Nevada.* Nevada provided a highway accident rate of 1.1×10^{-6} accident per kilometer (1.8×10^{-6} per mile) for interstate carriers over all road types. This is higher than the accident rate estimated by DIRS 103455-Saricks and Tompkins (1999, Table 4); 2.5×10^{-7} accident per kilometer (3.9×10^{-7} per mile) for heavy trucks over all road types in Nevada from 1994 to 1996.

  The definition of *accident* used in DIRS 103455-Saricks and Tompkins (1999, p. 4) is the Federal definition (fatality, injury, or tow-away); in Nevada the accident criteria are fatality, injury, or $750 property damage. Based on national data from the U.S. Department of Transportation Office of Motor Carrier Information Analysis (DIRS 103721-FHWA 1997, p. 2; DIRS 102231-FHWA 1998, pp. 1 and 2), using the Federal definition would reduce the accident rate from 1.1×10^{-6} to about 4.1×10^{-7} accident per kilometer (1.8×10^{-6} to 6.7×10^{-7} per mile). The radiological accident risk in Nevada for the mostly legal-weight truck scenario would increase over 24 years from 0.0002 latent cancer fatality to about 0.0005 latent cancer fatality (a likelihood of 5 in 10,000 of one latent cancer fatality) if the accident rate reported by DIRS 103455-Saricks and Tompkins (1999, p. 33) for Nevada were replaced by the rate of 4.1×10^{-7} per kilometer. Thus, the impacts of the rate for accidents involving large trucks on Nevada highways reported by Nevada (DIRS 104728-Denison 1998, all) would be comparable to the impacts derived using the rate estimated by DIRS 103455-Saricks and Tompkins (1999, p. 33).

- *California.* California responded with highway accident rates that included all vehicles (cars, buses, and trucks). The accident rate for Interstate highways was 4.2×10^{-7} accident per kilometer (6.8×10^{-7} per mile) for all vehicles in 1996. This rate is higher than the accident rate estimated by DIRS 103455-Saricks and Tompkins (1999, Table 4), 1.6×10^{-7} accident per kilometer (2.6×10^{-7} per mile) for heavy trucks on California interstate highways from 1994 to 1996.

  The definition of *accident* in DIRS 103455-Saricks and Tompkins (1999, p. 4) is the Federal definition (fatality, injury, or tow-away); in California the accident criteria are fatality, injury, or $500 property damage. Based on national data from DIRS 103721-FHWA (1997, p. 2) and DIRS 102231-FHWA (1998, pp. 1 and 2), using the Federal definition would reduce the accident rate from 4.2×10^{-7} to about 1.6×10^{-7} accident per kilometer (6.8×10^{-7} to 2.6×10^{-7} per mile). In addition, the rate provided by California was for all vehicles. Based on national data from the U.S. Department of Transportation Bureau of Transportation Statistics, using the accident rate for large trucks would reduce the all-vehicle accident rate from 1.6×10^{-7} to about 1.3×10^{-7} accident per kilometer (2.6×10^{-7} to 2.1×10^{-7} per mile) for large trucks. This rate is slightly less than the rate estimated by DIRS 103455-Saricks and Tompkins (1999, Table 4), 1.6×10^{-7} accident per kilometer.

- *Illinois.* Illinois provided highway data for semi-trucks from 1991 through 1995 over all road types. Over this period, the accident rate was 1.8×10^{-6} accident per kilometer (2.9×10^{-6} per mile). From 1994 through 1996, DIRS 103455-Saricks and Tompkins (1999, all) estimated an accident rate of 3.0×10^{-7} accident per kilometer (4.8×10^{-7} per mile) for heavy trucks over all road types in Illinois.

  The definition of *accident* used in DIRS 103455-Saricks and Tompkins (1999, p. 4) is the Federal definition (fatality, injury, or tow-away); in Illinois the accident criteria are fatality, injury, or $500 property damage. Based on national data from the U.S. Department of Transportation Office of Motor Carrier Information Analysis (DIRS 103721-FHWA 1997, p. 2; DIRS 102231-FHWA 1998, pp. 1 and 2), using the Federal definition would reduce the accident rate from 1.8×10^{-6} to about 6.7×10^{-7} accident per kilometer (2.9×10^{-6} to 1.1×10^{-6} per mile). This rate is comparable to the rate estimated by DIRS 103455-Saricks and Tompkins (1999, all).

- *Nebraska.* Nebraska provided a highway accident rate of 2.4×10^{-7} accident per kilometer (3.8×10^{-7} per mile) for 1997. Nebraska did not specify if the rate was for interstate highways, but it is for interstate truck carriers. This rate is slightly less than the accident rate estimated by DIRS 103455-Saricks and Tompkins (1999, all) for Nebraska interstates, 3.2×10^{-7} accident per kilometer (5.1×10^{-7} per mile) for heavy trucks from 1994 through 1996.

- *South Carolina.* South Carolina responded with highway accident rates that included all types of tractor/trailers (for example, mobile homes, semi-trailers, utility trailers, farm trailers, trailers with boats, camper trailers, towed motor homes, petroleum tankers, lowboy trailers, auto carrier trailers, flatbed trailers, and twin trailers). The rate was 8.3×10^{-7} accident per kilometer (1.3×10^{-6} per mile), for all road types. [This is higher than the accident rate estimated by DIRS 103455-Saricks and Tompkins (1999, all), 4.7×10^{-7} accident per kilometer (7.6×10^{-7} per mile) for heavy trucks on all road types in South Carolina from 1994 through 1996].

  The definition of *accident* in DIRS 103455-Saricks and Tompkins (1999, p. 4) is the Federal definition (fatality, injury, or tow-away); in South Carolina the accident criteria are fatality, injury, or $1,000 property damage. Based on national data from the U.S. Department of Transportation Office of Motor Carrier Information Analysis (DIRS 103721-FHWA 1997, p. 2; DIRS 102231-FHWA 1998, pp. 1 and 2), using the Federal definition of an accident would reduce the accident rate from 8.3×10^{-7} to about 3.1×10^{-7} accident per kilometer (1.3×10^{-6} to 5.0×10^{-7} per mile), which is slightly less than the rate estimated by DIRS 103455-Saricks and Tompkins (1999, all), 4.7×10^{-7} accident per kilometer (7.6×10^{-7} per mile). In addition, the accident rate estimated by DIRS 103455-Saricks and Tompkins (1999, all) was based on Motor Carrier Management Information System vehicle configuration codes 4 through 8 (truck/trailer, bobtail, tractor/semi-trailer, tractor/double, and tractor/triple), while the rate obtained from South Carolina included all truck/trailer combinations. Including all of the combinations tends to increase accident rates; for example, light trucks have higher accident rates than heavy trucks (DIRS 148081-BTS 1999, Table 3-22).

DOE evaluated the effect of using the data provided by the five states on radiological accident risk for the mostly legal-weight truck national transportation scenario. If the data used in the analysis for the five states (DIRS 103455-Saricks and Tompkins 1999, Table 4) were replaced by the data provided by the states with the adjustments discussed, the change in the resulting estimate of radiological accident risk would be small, increasing from 0.067 to 0.071 latent cancer fatality. Using the unadjusted data provided by those states would result in an increase in accident risk from 0.067 to 0.093 latent cancer fatality.

J.1.4.2.4 *Transportation Accidents Involving Nonradioactive Hazardous Materials*

The analysis of impacts of transportation accidents involving the transport of nonradioactive hazardous materials to and from Yucca Mountain used information presented in two U.S. Department of Transportation reports (DIRS 103718-DOT 1998, Table 1; DIRS 103708-BTS 1996, p. 43) on the annual number of hazardous materials shipments in the United States and the number of deaths caused by hazardous cargoes in 1995. In total, there are about 300 million annual shipments of hazardous materials; only a small fraction involve radioactive materials. In 1995, 6 fatalities occurred because of hazardous cargoes. These data suggest a rate of 2 fatalities per 100 million shipments of hazardous materials. DOE anticipates about 40,000 shipments of nonradioactive hazardous materials (including diesel fuel and laboratory and industrial chemicals) to and from the Yucca Mountain site during construction, operation and monitoring, and closure of the repository. Assuming that the rate for fatalities applies to the

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transportation of nonradioactive hazardous materials to and from Yucca Mountain, DOE does not expect fatalities from 40,000 shipments of these materials.

J.1.4.2.5 *Cost of Cleanup and Ecological Restoration Following a Transportation Accident*

Cost of Cleanup. According to the Nuclear Regulatory Commission report *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, pp. 7-73 to 7-76), in more than 99.99 percent of accidents radioactive material would not be released from the cask. After initial safety precautions had been taken, the cask would be recovered and removed from the accident scene. Because no radioactive material would be released, based on reported experience with two previous accidents (DIRS 156110-FEMA 2000, Appendix G, Case 4 and Case 5), the economic costs of these accidents would be minimal.

For the 0.01 percent of accidents severe enough to cause a release of radioactive material from a cask, a number of interrelated factors would affect costs of cleaning up resulting radioactive contamination after the accident. Included are: the severity of the accident and the initial level of contamination; the weather at the time and following; the location and size of the affected land area and how the land is used; the standard established for the allowable level of residual contamination following cleanup and the decontamination method used; and the technical requirements for and location for disposal of contaminated materials.

Because it would be necessary to specify each of the factors to estimate clean up costs, any estimate for a single accident would be highly uncertain and speculative. Nonetheless, to provide a gauge of the costs that could be incurred DOE examined past studies of costs of cleanup following hypothetical accidents that would involve uncontrolled releases of radioactive materials.

A study of the impacts of transporting radioactive materials conducted by the Nuclear Regulatory Commission in 1977 estimated that costs could range from about $1 million to $100 million for a transportation accident that involved a 600-curie release of a long-lived radionuclide (DIRS 101892-NRC 1977, Table 5-11). These estimates would be about 3 times higher if escalated for inflation from 1977 to the present. In 1980 DIRS 155054-Finley et al. (1980, Table 6-9) estimated that costs could range from about $90 million to $2 billion for a severe spent nuclear fuel transportation accident in an urban area. DIRS 154814-Sandquist et al. (1985, Table 3-7) estimated that costs could range from about $200,000 to $620 million. In this study, Sandquist estimated that contamination would affect between 0.063 to 4.3 square kilometers (16 to 1,100 acres). A study by DIRS 152083-Chanin and Murfin (1996, Chapter 6) estimated the costs of cleanup following a transportation accident in which plutonium would be dispersed. This study developed cost estimates for cleaning up and remediating farmland, urban areas, rangeland, and forests. The estimates ranged from $38 million to $400 million per square kilometer that would need to be cleaned up. The study also evaluated the costs of expedited cleanups in urban areas for light, moderate, and heavy contamination levels. These estimates ranged from $89 million to $400 million per square kilometer.

The National Aeronautics and Space Administration studied potential accidents for the Cassini mission, which used a plutonium powered electricity generator. The Agency estimated that costs of cleaning up radioactive material contamination on land following potential launch and reentry accidents. The estimate for the cost following a launch accident ranged from $7 million to $70 million (DIRS 155551-NASA 1995, Chapter 4) with an estimated contaminated land area of about 1.4 square kilometers (350 acres). The Agency assumed cleanup costs would be $5 million per square kilometer if removal and disposal of contaminated soil were not required and $50 million per square kilometer if those activities were required. For a reentry accident that would occur over land, the study estimated that the contaminated land area could range from about 1,500 to 5,700 square kilometers (370,000 to 1.4 million acres) (DIRS 155551-NASA 1995, Chapter 4) with cleanup costs possibly exceeding a total of $10 billion. In a more recent study of potential consequences of accidents that could involve the Cassini mission, NASA estimated that costs could range from $7.5 million to $1 billion (DIRS 155550-NASA 1997, Chapter 4). The contaminated land area associated with these costs ranged from 1.5 to 20 square kilometers (370 to 4,900 acres). As in the 1995 study, these estimates were based on cleanup costs in the range of $5 million to $50 million per square kilometer.

Using only the estimates provided by these studies, the costs of cleanup following a severe transportation accident involving spent nuclear fuel where radioactive material was released could be in the range from $300,000 (after adjusting for inflation from 1985 to the present) to $10 billion. Among the reasons for this wide range are different assumptions made regarding the factors that must be considered: 1) the severity of the assumed accident and resulting contamination levels, 2) accident location and use of affected land areas, 3) meteorological conditions, 4) cleanup levels and decontamination methods, and 5) disposal of contaminated materials. However, the extreme high estimates of costs are based on assumptions that all factors combine in the most disadvantageous way to create a "worst case." Such worst cases are not reasonably foreseeable. Conversely, estimates as low as $300,000 may also not be realistic for all of the direct and indirect costs of cleaning up following an accident severe enough to cause a release of radioactive materials.

To gauge the range of costs that it could expect for severe accidents in transporting spent nuclear fuel to a Yucca Mountain repository, DOE considered the spectrum of accidents that are reasonably foreseeable (see Section J.1.4.2.1) and the amount of radioactive material that could be released in each such accident and compared this to the estimates of releases used by the various studies discussed above. Based on 2 million curies of radioactive material in a rail casks loaded with spent nuclear fuel, about 13 curies (mostly cesium) would be released in a maximum reasonably foreseeable accident. This is about 100 times less than used by Sandquist in his study (1,630 curies) and 50 times less than the release used in the estimates provided by the Nuclear Regulatory Commission in 1977 (600 curies). The estimated frequency for an accident this severe to occur is about 3 times in 10 million years. Based on the prior studies (where estimated releases exceeded those estimated in this appendix for a maximum reasonably foreseeable accident) and the amount of radioactive material that could be released in a maximum reasonably foreseeable accident, the Department believes that the cost of cleaning up following such an accident could be a few million dollars. Nonetheless, as stated above, the Department also believes that estimates of such costs contain great uncertainty and are speculative; they could be less or 10 times greater depending on the contributing factors.

For perspective, the current insured limit of responsibility for an accident involving releases of radioactive materials to the environment is $9.43 billion (see Appendix M). The annual cost of transporting spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be about $200 million.

Ecological Restoration. Following a severe transportation accident, it might be necessary to restore the ecology of an area after the area was remediated. DIRS 152083-Chanin and Murfin (1996, all) present a review of the scope of ecological restoration that can be accomplished and the requirements that would apply in the event of an accident where environmental damage resulting from cleaning up radioactive material contamination would in turn result in a need for environmental restoration. The restoration that would be necessary following an accident cannot be predicted. It would depend on the environmental factors involved—1) the levels of contamination from the accident, 2) cleanup levels and decontamination methods used, and 3) location and ecology of the affected land areas—and the restoration goal that was used. DIRS 152083-Chanin and Murfin (1996, Chapter 6) observe

> *"[a] long-standing definition of the preferred goal of site restoration is to establish an ecological community as similar as possible to that which existed before an accident. Alternative goals are to*

establish a similar, but not identical, community; to establish an entirely different but valued community; or, if none of the foregoing is feasible, to establish some less-valued community."

The costs discussed above include costs for environmental restoration.

DIRS 152083-Chanin and Murfin (1996, all) provide the following assessments of environmental restoration that could be accomplished following clean up of contamination from an accident.

- Unassisted restoration of desert land is difficult, but assisted restoration can be very successful.
- Grasslands may be restored naturally provided only limited soil has been removed. Assisted restoration of prairies is also successful.
- Total restoration of forests may not be possible if the area is too large for natural reseeding; an alternative use may have to be found for forestland.
- Restoration of farmland is relatively simple.
- Restoration of urban land to building sites is simple.
- Restoration to parkland is possible, but more costly.

J.2 Evaluation of Rail and Intermodal Transportation

DOE could use several modes of transportation to ship spent nuclear fuel from the 72 commercial and 5 DOE sites. Legal-weight trucks could transport spent nuclear fuel and high-level radioactive waste in truck casks that would weigh approximately 22,500 kilograms (25 tons) when loaded. For sites served by railroads, railcars could be used to ship rail casks directly to the Yucca Mountain site, if a branch rail line was built in Nevada, or to an intermodal transfer station in Nevada if heavy-haul trucks were used. Rail casks would weigh as much as 136,000 kilograms (150 tons).

For sites that have the capability to load rail casks but are not served by a railroad, DOE could use heavy-haul trucks or, for sites on navigable waterways, barges to transport casks to nearby railheads.

For rail shipments, DOE could request the railroads to provide dedicated trains to transport casks from the sites to a destination in Nevada or could deliver railcars with loaded casks to the railroads as general freight for delivery in Nevada.

In addition, DOE evaluated the potential for including two other scenarios: (1) a different mostly rail scenario in which railcars would transport legal-weight truck casks and (2) a large-scale barge scenario.

J.2.1 LEGAL-WEIGHT TRUCK CASKS ON RAILCARS SCENARIO

DOE assessed the sensitivity of transportation impacts to assumptions related to transportation scenarios. The analysis evaluated a variation of the mostly rail scenario in which shipments would be made using casks much smaller than rail casks—legal-weight truck casks—shipped to Nevada on railcars then transported on legal-weight trucks from a rail siding to Yucca Mountain. Under this scenario, because all shipments (except shipments of naval spent nuclear fuel) would use legal-weight truck casks, the number of railcar shipments would be about 53,000 over the 24 years of the Proposed Action. This would be the same as the number of legal-weight truck plus naval spent nuclear fuel shipments in the mostly legal-weight truck scenario.

DOE estimated impacts of this variation of the mostly rail transportation scenario by scaling from the impacts estimated for the mostly rail scenario. The analysis used the ratio of the number of railcars that would be shipped to the number of railcar shipments estimated for the mostly rail scenario and assumed each shipment would include an escort car and five railcars carrying legal-weight truck casks. The estimated number of public incident-free latent cancer fatalities would be approximately 4, and the estimated number of traffic fatalities would be 8. The total of these estimates, 12, is about 1.5 times the DOE revised estimate of a total of 7 fatalities (2.5 latent cancer fatalities plus 4.5 traffic fatalities) for the legal-weight truck scenario.

DOE determined that while this scenario would be feasible, it would not be practical. The number of shipping casks and railcar shipments would be greater by a factor of 5 than for the mostly rail scenario and the additional cost to the Program would be more than $1 billion. In addition, the truck-casks-on-railcars scenario would lead to the highest estimates of occupational health and public health and safety impacts, most coming from rail-traffic related facilities.

J.2.2 LARGE-SCALE BARGE SCENARIO

In response to public comments on the 1986 Environmental Assessment for the Yucca Mountain Site, Research and Development Area, Nevada (DIRS 104731-DOE 1986, p. C.2-40), DOE described barge transportation as a feasible alternative that could play a secondary or supplementary role in the transportation of radioactive wastes to a repository. In the Final Environmental Impact Statement on Management of Commercially Generated Radioactive Waste (DIRS 104832-DOE 1980, Volume A, pp. 4.64 and 4.65), DOE concluded that barge transport is an alternative when both the nuclear powerplant and the encapsulation or storage facility are on navigable waterways. That EIS observed that barge transport suggests high payloads and low tariffs, but cost gains in these two areas could be offset by the longer estimated transit times for barge shipments. The EIS also observed that casks for barge shipment of spent nuclear fuel probably would be similar, if not identical, to those used for rail transport.

The most likely way in which DOE would use barge transportation to make shipments to a repository would be to complete a leg of the trip that also involved two land legs. Even though many generator sites are adjacent to or near navigable waterways, shipping casks cannot be loaded directly onto barges in all cases. It would be necessary to use heavy-haul trucks or railcars to transport the casks from the generator site’s cask loading facilities to a barge slip or dock. The casks would then either be rolled onto the barge using the land vehicle and a loading ramp and secured to the barge deck or hoisted from the land vehicle to the barge and secured. At the destination end of the barge leg of the trip, the cask would either be rolled off the barge using a ramp and a heavy-haul truck or hoisted from the barge deck onto a railcar or heavy-haul truck. The cask probably would then be transported from the destination port to Nevada by rail and not by heavy-haul truck. Thus, if casks were rolled off barges to heavy-haul trucks, they would need to be transferred to railcars. The maximum use of barge transportation would require transport through the Panama Canal for shipments from generator sites in the middle and eastern part of the United States. Such use could result in 70 percent fewer land travel kilometers than the mostly rail or mostly legal-weight truck scenario.

Analyses in the 1986 Environmental Assessment (DIRS 104731-DOE 1986, p. A-69) showed that the use of barge transportation would generally increase occupational exposure for normal shipment operations and could increase exposure of the public because of intermodal transfers. From the analyses, reactor-specific results suggest that under several circumstances the barge mode could reduce risk. The analyses concluded that the consequences of accidents from barges would be of the same magnitude as those for other modes.

Because, as discussed above, DOE could use barge transportation only in conjunction with land modes, DOE did not evaluate barge as an alternative major modal scenario as it did for the mostly rail and mostly

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legal-weight truck modal scenarios. Rather, for the 17 commercial generator sites not served by railroads but situated near or adjacent to navigable waterways, DOE evaluated and compared the potential use of barges and heavy-haul trucks to transport casks containing spent nuclear fuel from these sites to nearby railheads. The analysis assumed barges or heavy-haul trucks would be offloaded at the railheads and the casks would be transferred to railcars for shipment to Nevada.

DOE eliminated the large-scale barge scenario from further consideration in the EIS because it would be overly complex, requiring greater logistical complexity than either rail or legal-weight truck transportation; a much greater number of large rail casks than rail transport; much greater cost than either rail or legal-weight truck transportation; long transport distances potentially requiring the transit of the Panama Canal outside U.S. territorial waters; transport on intercoastal and coastal waterways of coastal states and on major rivers through and bordering states; extended transportation times; intermodal transfer operations at ports; and land transport from a western port to Yucca Mountain. If in the future DOE concluded that barge transportation was reasonable and proposed to make use of it, the Department would conduct additional National Environmental Policy Act evaluations to assess potential impacts of the greater use.

J.2.3 EFFECTS OF USING DEDICATED TRAINS OR GENERAL FREIGHT SERVICE

The Association of American Railroads recommends that only special (dedicated) trains move spent nuclear fuel and certain other forms of radioactive materials (DIRS 103718-DOT 1998, p. 2-6). In developing its recommendation, the Association concluded that the use of special trains would provide operational (for railroads and shippers) and safety advantages over shipments that used general freight service. Notwithstanding this recommendation, the U.S. Department of Transportation study (DIRS 103718-DOT 1998, all) compared dedicated and regular freight service using factors that measure impacts to overall public safety. The results of this study indicated that dedicated trains could provide advantages over regular trains for incident-free transportation but could be less advantageous for accident risks. However, available information does not indicate a clear advantage for the use of either dedicated trains or general freight service. Thus, DOE has not determined the commercial arrangements it would request from railroads for shipment of spent nuclear fuel and high-level radioactive waste. Table J-25 compares the dedicated and general freight modes. These comparisons are based on the findings of the U.S. Department of Transportation study and the Association of American Railroads.

J.2.4 IMPACTS OF THE SHIPMENT OF COMMERCIAL SPENT NUCLEAR FUEL BY BARGE AND HEAVY-HAUL TRUCK FROM 24 SITES NOT SERVED BY A RAILROAD

The mostly rail scenario includes 24 sites that do not have direct rail access. For those sites, heavy-haul trucks would be used to haul the spent nuclear fuel casks to the nearest railhead. As shown in Figure J-9 (a multipage figure), 17 of the 24 sites are on navigable waterways, so barge transport could be a feasible way to move spent nuclear fuel to the closest railhead with barge access. This section estimates the changes in impacts to the mostly rail scenario if barge transport replaced heavy-haul truck transport for these 17 sites.

J.2.4.1 Routes for Barges and Heavy-Haul Trucks

The distances from the 24 sites to railheads range from about 6 to 75 kilometers (4 to 47 miles). DOE used the HIGHWAY computer code to estimate routing for heavy-haul trucks (DIRS 104780-Johnson et al. 1993, all). The INTERLINE computer code (DIRS 104781-Johnson et al. 1993, all) was used to generate route-specific distances that would be traveled by barges. Table J-26 lists estimates for route lengths for barges and heavy-haul trucks. Table J-27 lists the number of shipments from each site.

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Table J-25. Comparison of general freight and dedicated train service.

Attribute	General freight	Dedicated train
Overall accident rate for accidents that could damage shipping casks	Same as mainline railroad accident rates	Expected to be lower than general freight service because of operating restrictions and use of the most up-to-date railroad technology.
Grade crossing, trespasser, worker fatalities	Same as mainline railroad rates for fatalities	Uncertain. Greater number of trains could result in more fatalities in grade crossing accidents. Fewer stops in classification yards could reduce work related fatalities and trespasser fatalities.
Security	Security provided by escorts required by NRC[a] regulations	Security provided by escorts required by NRC regulations; fewer stops in classification yards than general freight service.
Incident-free dose to public	Low, but more stops in classification yards than dedicated trains. However, classification yards would tend to be remote from populated areas.	Lower than general freight service. Dedicated trains could be direct routed with fewer stops in classification yards for crew and equipment changes.
Radiological risks from accidents	Low, but greater than dedicated trains	Lower than general freight service because operating restrictions and equipment could contribute to lower accident rates and reduced likelihood of maximum severity accidents.
Occupational dose	Duration of travel influences dose to escorts	Shorter travel time would result in lower occupational dose to escorts.
Utilization of resources	Long cross-country transit times could result in least efficient use of expensive transportation cask resources; best use of railroad resources; least reliable delivery scheduling; most difficult to coordinate state notifications.	Direct through travel with on-time deliveries would result in most efficient use of cask resources; least efficient use of railroad resources. Railroad resource demands from other shippers could lead to schedule and throughput conflicts. Easiest to coordinate notification of state officials.

a. NRC = U.S. Nuclear Regulatory Commission.

J.2.4.2 Analysis of Incident-Free Impacts for Barge and Heavy-Haul Truck Transportation

J.2.4.2.1 *Radiological Impacts of Incident-Free Transportation*

This section compares radiological and nonradiological impacts to populations, workers, and maximally exposed individuals for the mostly rail case when casks from heavy-haul truck transport would be switched to barge for 17 of the 24 heavy haul truck sites. To make the comparison, the analysis retained any assumptions not affected by the mode change for the 17 sites. Thus:

- The seven sites that would ship by heavy-haul truck and do not have barge access would ship by heavy-haul truck in the barge case.
- The sites that would ship by legal-weight truck in the mostly rail case still ship by legal-weight truck for the barge analysis.
- For the rail segments of the routes that would use barge transport, separate INTERLINE runs determined the routes from the closest barge dock with rail access to each of the six end nodes in Nevada. While these routes are normally the same outside the origin state, no restrictions were imposed on INTERLINE requiring that the routes outside the origin state be the same.

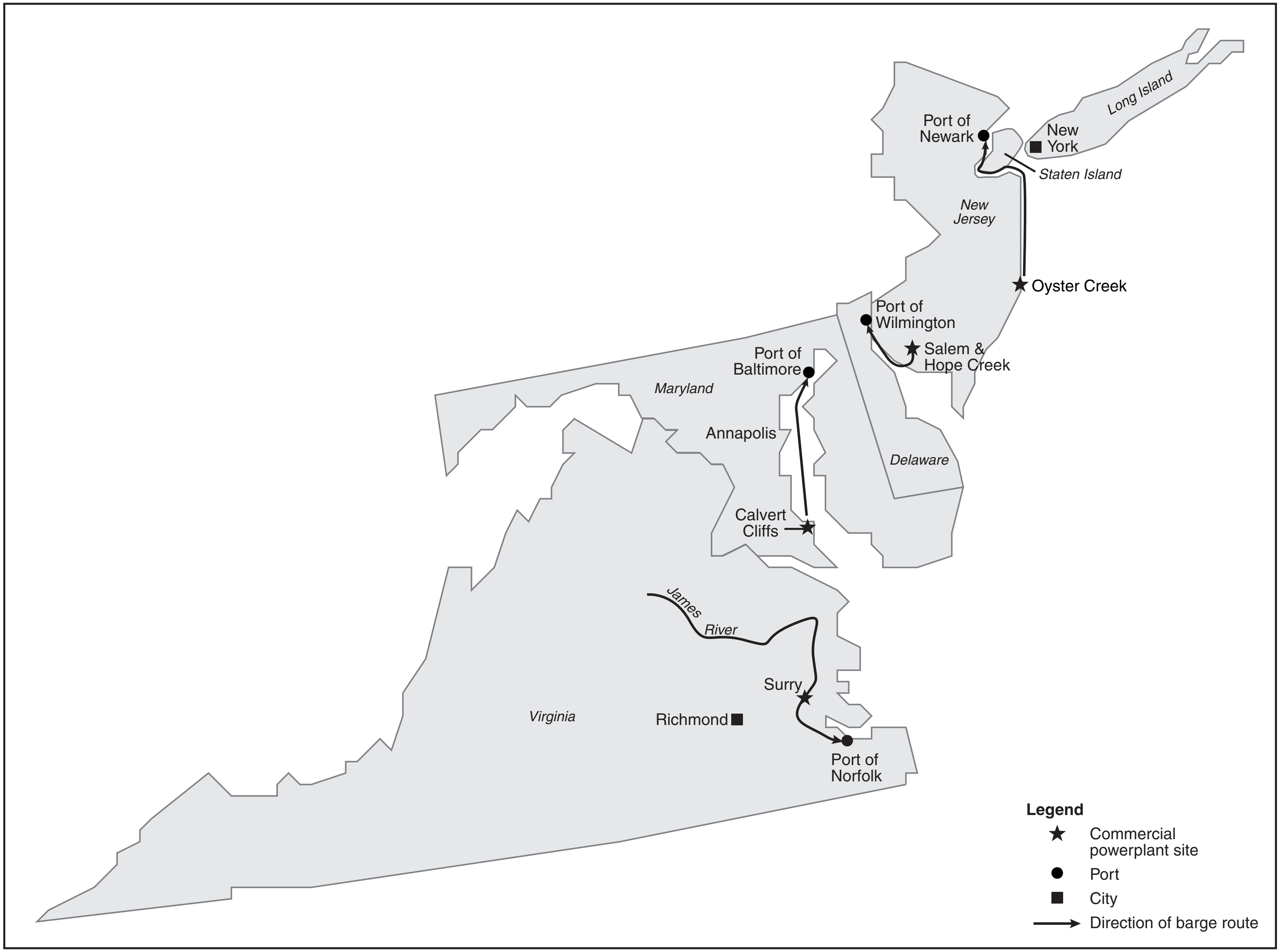

Figure J-9. Routes analyzed for barge transportation from sites to nearby railheads (page 1 of 4).

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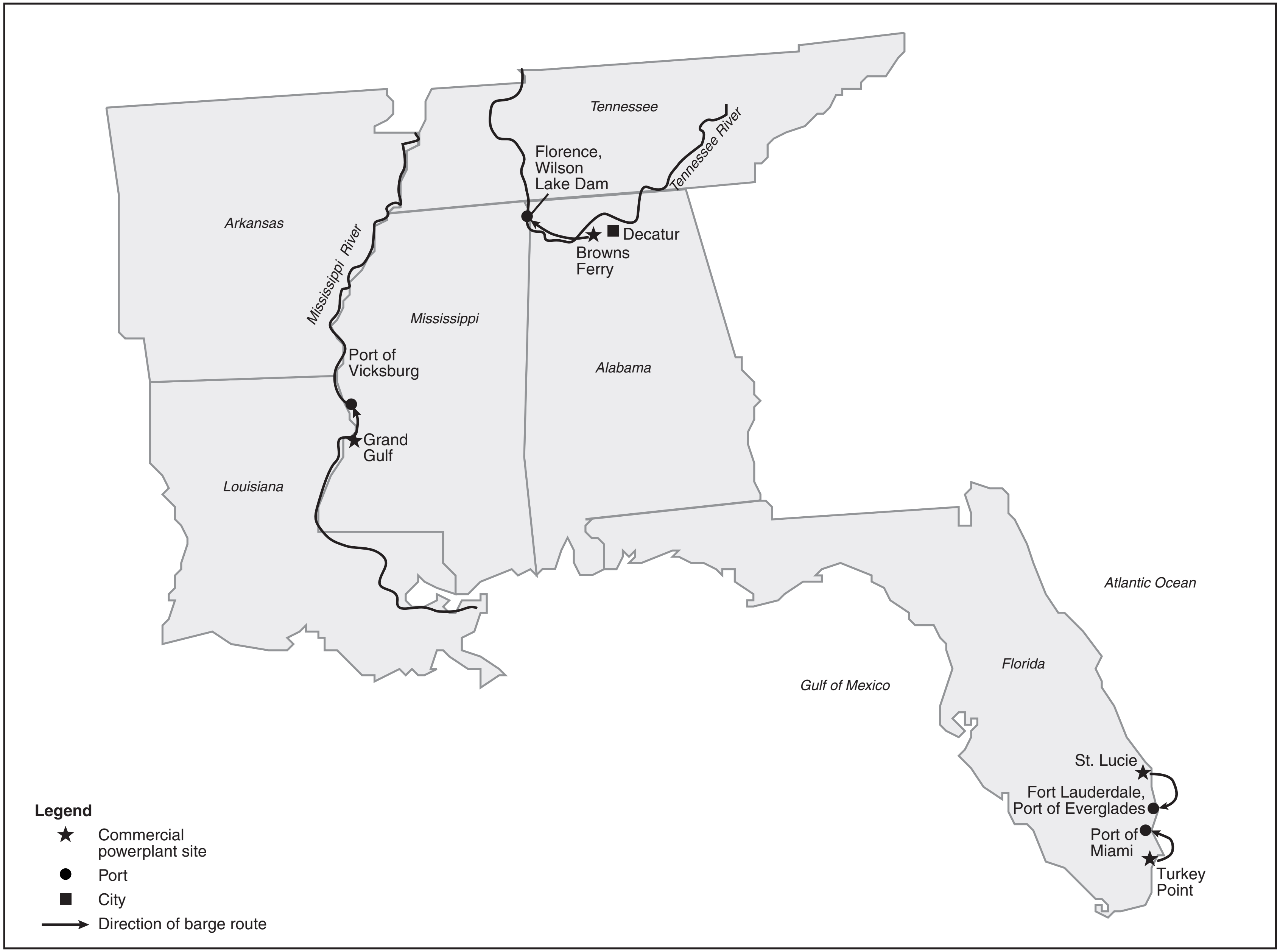

Figure J-9. Routes analyzed for barge transportation from sites to nearby railheads (page 2 of 4).

Figure J-9. Routes analyzed for barge transportation from sites to nearby railheads (page 3 of 4).

Figure J-9. Routes analyzed for barge transportation from sites to nearby railheads (page 4 of 4).

Table J-26. National transportation distances from commercial sites to Nevada ending rail nodes (kilometers).[a,b]

Site (intermodal rail node)[c]	Rail transportation Total[d]	Rural	Suburban	Urban	Barge transportation Total[d]	Rural	Suburban	Urban
Browns Ferry NP[e]	3,279 - 3,656	2,985 - 3,306	260 - 300	34 - 49	57	51	5	0
Calvert Cliffs NP	4,028 - 4,404	3,270 - 3,592	610 - 650	148 - 162	99	98	2	0
Cooper NP	2,029 - 2,405	1,910 - 2,231	98 - 138	21 - 36	117	100	16	1
Diablo Canyon NP	582 - 1,453	375 - 1,006	112 - 311	94 - 136	143	143	0	0
Grand Gulf NP	3,298 - 3,665	2,859 - 3,333	270 - 373	28 - 67	51	51	0	0
Haddam Neck NP	4,339 - 4,716	3,316 - 3,637	842 - 882	182 - 197	99	89	10	0
Hope Creek NP	4,229 - 4,605	3,458 - 3,779	655 - 695	116 - 131	30	30	0	0
Indian Point NP	4,351 - 4,727	3,425 - 3,746	766 - 806	160 - 175	68	13	39	15
Kewaunee NP	2,864 - 3,241	2,506 - 2,827	291 - 331	68 - 82	177	171	1	5
Oyster Creek NP	4,337 - 4,714	3,420 - 3,741	765 - 806	152 - 167	130	77	36	17
Palisades NP	3,060 - 3,436	2,607 - 2,929	355 - 395	97 - 112	256	256	0	0
Pilgrim NP	4,393 - 4,769	3,338 - 3,659	858 - 899	196 - 211	74	41	33	0
Point Beach NP	2,864 - 3,241	2,506 - 2,827	291 - 331	68 - 82	169	163	1	5
Salem NP	4,229 - 4,605	3,458 - 3,779	655 - 695	116 - 131	34	34	0	0
St. Lucie NP	4,840 - 5,136	3,934 - 4,205	756 - 842	87 - 139	140	50	52	38
Surry NP	4,403 - 4,780	3,773 - 4,094	554 - 595	76 - 90	71	60	8	3
Turkey Point NP	4,882 - 5,178	3,937 - 4,208	765 - 851	117 - 169	54	53	0	1
Big Rock Point NP HH – 20.0 kilometers	3,258 - 3,595	2,766 - 3,059	399 - 431	93 - 105	--[f]	--	--	--
Callaway NP HH – 18.5 kilometers	2,491 - 2,868	2,352 - 2,674	119 - 159	20 - 35	--	--	--	--
Fort Calhoun NP HH – 6.0 kilometers	1,997 - 2,373	1,905 - 2,227	81 - 122	10 - 25	--	--	--	--
Ginna NP HH – 35.1 kilometers	3,532 - 3,869	2,792 - 3,086	604 - 636	136 - 147	--	--	--	--
Oconee NP HH – 17.5 kilometers	3,999 - 4,375	3,470 - 3,792	475 - 515	54 - 68	--	--	--	--
Peach Bottom NP HH – 58.9 kilometers	4,110 - 4,486	3,383 - 3,704	616 - 656	111 - 126	--	--	--	--
Yankee Rowe NP HH – 10.1 kilometers	3,998 - 4,335	3,083 - 3,376	752 - 784	164 - 175	--	--	--	--

a. To convert kilometers to miles, multiply by 0.62137.
b. Distances estimated using INTERLINE computer program. Salem/Hope Creek treated as two sites.
c. Intermodal rail nodes selected for purpose of analysis. Source: (DIRS 104800-CRWMS M&O 1999, all).
d. Totals might differ from sums of rural, suburban, and urban distances due to method of calculation and rounding.
e. NP = nuclear plant.
f. -- = sites not located on a navigable waterway.

The analysis included radiological impacts of intermodal transfers at the interchange from heavy-haul trucks to railcars or barges to railcars. Workers would be exposed to radiation from casks during transfer operations. However, because the transfers would occur in terminals and berths remote from public access, public exposures would be small. Impacts of constructing intermodal transfer facilities were not included because intermodal transfers were assumed to take place at existing facilities.

The analysis assumed that heavy-haul trucks would travel at a lower speed than legal-weight trucks and that barge transport would be even slower. The assumed speed was 40 kilometers (25 miles) per hour and 8 kilometers (5 miles) per hour for heavy-haul truck and barge transport, respectively. These speeds were assumed to be independent of any population zone. Because travel distances to nearby railheads are short in relation to the distances traveled by rail, the expected impacts of heavy-haul truck and barge transportation would be much smaller than those of national rail shipments. The analysis of impacts for barge shipments assumed that the transport would employ commercial vessels operated by maritime

Table J-27. Barge shipments and ports.

Plant name	State	Number of shipments: Proposed Action	Module 1	Module 2	Barge ports assumed for barge-to-rail intermodal transfer
Browns Ferry 1	AL	122	247	248	Wilson Loading Dock
Browns Ferry 2	AL	0	0	1	Wilson Loading Dock
Browns Ferry 3	AL	51	120	121	Wilson Loading Dock
Diablo Canyon 1	CA	60	148	150	Port Huememe
Diablo Canyon 2	CA	61	160	162	Port Huememe
Haddam Neck	CT	40	40	42	Port of New Haven
St. Lucie 1	FL	12	13	16	Port Everglades
St. Lucie 2	FL	61	147	150	Port Everglades
Turkey Point 3	FL	52	85	87	Port of Miami
Turkey Point 4	FL	52	86	88	Port of Miami
Calvert Cliffs 1	MD	169	320	323	Port of Baltimore
Calvert Cliffs 2	MD	0	0	3	Port of Baltimore
Pilgrim	MA	24	18	19	Port of Boston
Palisades	MI	70	122	125	Port of Muskegon
Grand Gulf 1	MS	80	215	216	Port of Vicksburg
Cooper Station	NE	42	124	125	Port of Omaha
Hope Creek	NJ	67	105	106	Port of Wilmington
Oyster Creek 1	NJ	64	110	111	Port of Newark
Salem 1	NJ	59	101	103	Port of Wilmington
Salem 2	NJ	54	108	110	Port of Wilmington
Indian Point 1	NY	0	0	1	Port of Jersey City
Indian Point 2	NY	35	34	36	Port of Jersey City
Indian Point 3	NY	22	19	21	Port of Jersey City
Surry 1	VA	197	330	332	Port of Norfolk
Surry 2	VA	0	0	2	Port of Norfolk
Kewaunee	WI	64	110	111	Port of Milwaukee
Point Beach 1	WI	130	213	215	Port of Milwaukee
Point Beach 2	WI	0	0	2	Port of Milwaukee
Totals		***1,575***	***2,952***	***3,004***	

carriers on navigable waterways and that these shipments would follow direct routing from the sites to nearby railheads. For both modes, intermodal transfers would be necessary to transfer the casks to railcars.

The analysis estimated radiological impacts during transport for workers and the general population. For heavy-haul truck shipments, workers included vehicle drivers and escorts. For barge shipments, workers included five crew members on board during travel. In both the heavy-haul truck and barge cases, the workers would be far enough from the cask such that the major exposure would occur during periodic walkaround inspections. In both cases, consistent with the as-low-as-reasonably-achievable requirement guiding worker exposure, the analysis assumed that only one individual would perform these inspections. The general population for truck shipments included persons within 800 meters (about 2,600 feet) of the road (offlink), persons sharing the road (onlink), and persons at stops. The general population for barging included persons within a range of 200 to 1,000 meters (about 660 to 3,300 feet) of the route. Consistent with normal barge operations, the periodic walkaround inspections would occur while the barge was in motion and there was sufficient crew on board to eliminate the need for intermediate rest stops. Consistent with the RADTRAN 5 modeling, onlink exposures to members of the public during barging were assumed to be negligible. Incident-free unit risk factors were developed to calculate occupational and general population collective doses. Table J-28 lists the unit risk factors for heavy-haul truck and barge shipments. These factors reflect the effects of slower operating speeds for those vehicles in comparison to those for legal-weight trucks.

Table J-29 lists the incident-free impacts using the three shipment scenarios listed above. Impacts of intermodal transfers are included in the results. Occupational impacts would include the estimated radiological exposures of security escorts.

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Table J-28. Risk factors for incident-free heavy-haul truck and barge transportation of spent nuclear fuel and high-level radioactive waste.

Mode	Exposure group	Incident-free risk factors (person-rem per kilometer)[a]		
		Rural	Suburban	Urban
Heavy-haul truck	*Occupational*			
	Onlink[b]	5.54×10^{-6}	5.54×10^{-6}	5.54×10^{-6}
	Stops[b]	1.45×10^{-5}	1.45×10^{-5}	1.45×10^{-5}
	General population			
	Offlink[c]	6.24×10^{-8}	6.24×10^{-8}	6.24×10^{-8}
	Onlink[b]	1.01×10^{-4}	7.94×10^{-5}	2.85×10^{-4}
	Stops[b]	3.96×10^{-9}	3.96×10^{-9}	3.96×10^{-9}
	Overnight stop	2.62×10^{-3}		
Barge	*Occupational*[d]	2.11×10^{-6}	2.11×10^{-6}	2.11×10^{-6}
	General population			
	Offlink[c]	1.72×10^{-7}	1.72×10^{-7}	1.72×10^{-7}
	Onlink[b]	0.0	0.0	0.0
	Stops	0.0	0.0	0.0

a. The unit dose factors are developed from the equations in DIRS 155430-Neuhauser, Kanipe, and Weiner (2000, all) in the same way as the unit dose factors in Section J.1.3.

b. Onlink and stopped risk factors consider the exposure to the general population sharing the road and the crew transporting the cask. These factors must be multiplied by the number of shipments and the distance in kilometers in the zone for each segment of the route. The onlink vehicle density for rural transportation in Nevada was estimated using the annual average daily traffic on I-15 at the California-Nevada border (DIRS 103405-NDOT 1997, p. 4).

c. Offlink general population included persons from 30 to 800 meters (about 100 to 2,600 feet) of the road or railway and from 200 and 1,000 meters (about 650 and 3,300 feet) for barge. This risk factor must be multiplied by the number of shipments, distance in kilometers in the zone, and the population density (individuals per square kilometer) in the zone for each segment of the route.

d. Because heavy-haul vehicles cannot be in transit in Nevada for more than 12 hours, an overnight stop is modeled for routes that would require trips longer than 12 hours. This stop is not modeled for the short distances between reactor sites and railheads for indirect rail sites. When used, the factor is multiplied by the number of shipments.

Table J-29. Comparison of population doses and impacts from incident-free national transportation mostly rail heavy-haul truck scenario, mostly rail barge scenario, and mostly truck scenario.[a,b]

Category	Mostly rail (heavy-haul truck)[c]	Mostly rail (barge from 17 of 24 heavy-haul sites)[c]	Mostly truck
Involved worker			
Collective dose (person-rem)	4,300	4,400	14,100
Estimated LCFs[d]	1.7	1.7	5.6
Public			
Collective dose (person-rem)	1,500	1,400	5,000
Estimated LCFs	0.8	0.7	2.5
Maximally exposed individual			
Dose (rem)	0.29	0.29	3.2
Estimated emissions fatalities	0.0001[e]	0.0001[e]	0.0016[f]

a. Impacts are totals for all shipments over 24 years.

b. Includes impacts from intermodal transfer station (see Section 6.3.3.1).

c. Nevada impacts for the mostly rail routes have been averaged to show the effects of using barges at the origin.

d. LCF = latent cancer fatality.

e. Resident near a rail stop.

f. Person at a service station.

As indicated in Table J-29, the differences between the two mostly rail scenarios, heavy-haul truck and barge to nearby railheads, would be much smaller than the differences between the mostly rail scenarios and the mostly truck scenario. Considering only the mostly rail case options, heavy-haul and barge, the slower speed of the barge would tend to make barge exposures higher and the closest distance to resident population, 30 meters (100 feet) versus 200 meters (660 feet) for heavy-haul and barge, respectively, would tend to make barge exposures lower. Differences in the total exposed population or travel distances between the heavy-haul truck and barge routes could result in differences in the collective dose. Table J-29 indicates that the collective dose to the general public would be about the same as the barge case. Because workers would be well away from the cask during transport, the collective dose to workers would depend totally on the number of inspections performed during transit. Table J-29 indicates that these differences would be small. Based on this table, the barge scenario would have approximately the same impacts as the heavy-haul truck scenario that DOE used as a basis for the mostly rail results in Section J.1.3 and J.1.4.

J.2.4.2.2 *Nonradiological Impacts of Incident-Free Transportation (Vehicle Emissions)*

Table J-30 compares the estimated number of fatalities from vehicle emissions from shipments, assuming the use of heavy-haul trucks or barges to ship to nearby railheads.

Table J-30. Estimated population health impacts from vehicle emissions during incident-free national transportation for mostly rail heavy-haul truck and barge scenarios and the mostly legal-weight truck scenario.[a]

Category	Mostly rail (heavy-haul from 24 sites)	Mostly rail (heavy-haul truck from 7 sites and barge from 17)	Mostly truck
Estimated fatalities	0.63	0.62	0.93

a. Impacts are totals over 24 years, including impacts from an intermodal transfer station (see Chapter 6, Section 6.3.3.1).

J.2.4.3 Analysis of Impacts of Accidents for Barge and Heavy-Haul Truck Transportation

J.2.4.3.1 *Radiological Impacts of Accidents*

The analysis of risks from accidents during heavy-haul truck, rail, and legal-weight truck transport of spent nuclear fuel and high-level radioactive waste used the RADTRAN 5 computer code (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) in conjunction with an Access database and the analysis approach discussed in Section J.1.4.2. The analysis of risks due to barging used the same methodology with the exception of conditional probabilities. For barge shipments, the conditional accident probabilities and release fractions (Table J-31) for each cask response category were based on a review of other barge accident analyses.

The definitions of the accident severities listed in Table J-31 are based on the analyses reported in DIRS 152476-Sprung et al. (2000, pp. 7-75 to 7-76). DOE used the same accident severity category definitions as those used in the rail analysis described in Section J.1.4.2. If radioactive material was shipped by barge, both water and land contamination would be possible. DIRS 104784-Ostmeyer (1986, all) analyzed the potential importance of water pathway contamination for a spent nuclear fuel transportation accident risk using a "worst-case" water contamination scenario. The analysis showed that the impacts of the water contamination scenario would be about one-fiftieth of the impacts of a comparable accident on land. Therefore, the analysis assumed that deposition would occur over land, not water. DOE used population distributions developed from 1990 Census data to calculate route-specific collective doses. Table J-32 lists the total accident risk for mostly rail case heavy-haul truck scenario, the mostly rail case barge scenario, and the mostly truck scenario. Additional information is in Volume IV.

J.2.4.3.2 *Nonradiological Accident Risks*

As listed in Table J-32, the estimated total fatalities for the mostly rail heavy-haul truck scenario, the mostly rail barge scenario, and the mostly truck scenario would be 2.7, 2.7, and 4.5, respectively. There is essentially no difference between the two mostly rail scenarios. The only significant differences are between those scenarios, and the mostly truck case.

Table J-31. Release fractions and conditional probabilities for spent nuclear fuel transported by barge.

Severity category	Case	Conditional probability	Release fractions (pressurized-water reactor/boiling-water reactor)				
			Krypton	Cesium	Ruthenium	Particulates	Crud
1	21	0.994427	0.0	0.0	0.0	0.0	0.0
2	1, 4, 5, 7, 8	5.00×10^{-3}	$1.96 \times 10^{-1}/2.35 \times 10^{-2}$	$5.87 \times 10^{-9}/7.04 \times 10^{-10}$	$1.34 \times 10^{-7}/1.47 \times 10^{-8}$	$1.34 \times 10^{-7}/1.47 \times 10^{-8}$	$1.37 \times 10^{-3}/5.59 \times 10^{-4}$
3	20	5.00×10^{-6}	$8.39 \times 10^{-1}/8.39 \times 10^{-1}$	$1.68 \times 10^{-5}/1.68 \times 10^{-5}$	$2.52 \times 10^{-7}/2.52 \times 10^{-7}$	$2.52 \times 10^{-7}/2.52 \times 10^{-7}$	$9.44 \times 10^{-3}/9.44 \times 10^{-2}$
4	2, 3, 10	5.00×10^{-4}	$8.00 \times 10^{-1}/8.00 \times 10^{-1}$	$8.71 \times 10^{-6}/8.71 \times 10^{-6}$	$1.32 \times 10^{-5}/1.32 \times 10^{-5}$	$1.32 \times 10^{-5}/1.32 \times 10^{-5}$	$4.42 \times 10^{-3}/4.42 \times 10^{-2}$
5	6	0.0	$8.35 \times 10^{-1}/8.37 \times 10^{-1}$	$3.60 \times 10^{-5}/4.12 \times 10^{-5}$	$1.37 \times 10^{-5}/1.82 \times 10^{-5}$	$1.37 \times 10^{-5}/1.82 \times 10^{-5}$	$5.36 \times 10^{-3}/5.43 \times 10^{-3}$
6	9,11,12,13,14,15,16, 17,18,19	1.30×10^{-6}	$8.47 \times 10^{-1}/8.45 \times 10^{-1}$	$5.71 \times 10^{-5}/7.30 \times 10^{-5}$	$4.63 \times 10^{-5}/5.94 \times 10^{-5}$	$1.43 \times 10^{-5}/1.96 \times 10^{-5}$	$1.59 \times 10^{-2}/1.60 \times 10^{-2}$

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Table J-32. Comparison of accident risks for the mostly rail heavy-haul truck and barge shipping scenarios.[a]

Category	Mostly rail (heavy-haul option–24 sites)	Mostly rail (barge option–17 of 24 heavy-haul sites)	Mostly truck
Population dose (person-rem)	0.89	1.5	0.5
Estimated LCFs[b]	0.00045	0.001	0.0002
Traffic fatalities[c]	2.7	2.7	4.5

a. Impacts are totals over 24 years.
b. LCF = latent cancer fatality.
c. Traffic fatality impacts for mostly rail scenarios are the average of the range of estimated traffic fatality impacts (2.3 to 3.1) for national transportation for the Proposed Action.

J.2.4.3.3 *Maximum Reasonably Foreseeable Accidents*

From a consequence standpoint, because DOE used the same accident severity bins for rail, heavy-haul truck, and barge transport, the consequences of a release would be the same if the accident occurred in a zone having the same population density. The population densities for barge and heavy-haul truck transport are similar to those for rail. Because the total shipping distance traveled by barge or heavy-haul truck would be a small fraction of the total distance traveled, the maximum reasonably foreseeable accident would be a rail accident. Only minor barge or heavy-haul truck transport accidents would meet the 1×10^{-7} criterion used to identify reasonably foreseeable accidents.

J.3 Nevada Transportation

With the exceptions of the possible construction of a branch rail line or upgrade of highways for use by heavy-haul trucks and the construction of an intermodal transfer station, the characteristics of the transportation of spent nuclear fuel and high-level radioactive waste in Nevada would be similar to those for transportation in other states across the nation. Unless the State of Nevada designated alternative or additional preferred routes as prescribed under regulations of the U.S. Department of Transportation (49 CFR 397.103), Interstate System Highways (I-15) would be the preferred routes used by legal-weight trucks carrying spent nuclear fuel and high-level radioactive waste. Unless alternative or non-Interstate System routes have been designated by states, Interstate System highways would also be the preferred routes used by legal-weight trucks in other states during transit to Nevada.

In Nevada as in other states, rail shipments would, for the most part, be transported on mainline tracks of major railroads. Operations over a branch rail line in Nevada would be similar to those on a mainline railroad, except the frequency of train travel would be much lower. Shipments in Nevada that used heavy-haul trucks would use Nevada highways in much the same way that other overdimensional, overweight trucks use the highways along with other commercial vehicle traffic.

Some State- and county-specific assumptions were used to analyze human health and safety impacts in Nevada. A major difference would be that much of the travel in the State would be in rural areas where population densities are much lower than those of many other states. Another difference would be for travel in an urban area in the state. The most populous urban area in Nevada is the Las Vegas metropolitan area, which is also a major resort area with a high percentage of nonresidents. The analysis also addressed the channeling of shipments from the commercial and DOE sites into the transportation arteries in the southern part of the State. Finally, the analysis addressed the commuter and commercial travel that would occur on highways in the southern part of the State as a consequence of the construction, operation and monitoring, and closure of the proposed repository.

This section presents information specific to Nevada that DOE used to estimate impacts for transportation activities that would take place in the State. It includes results for cumulative impacts that would occur in Nevada for transportation associated with Inventory Modules 1 and 2.

J.3.1 TRANSPORTATION MODES, ROUTES, AND NUMBER OF SHIPMENTS

J.3.1.1 Routes in Nevada for Legal-Weight Trucks

The analysis of impacts that would occur in Nevada used the characteristics of highways in Nevada that would be used for shipments of spent nuclear fuel and high-level radioactive waste by legal-weight trucks. Specifically, the base case for the analysis used routing for the Las Vegas Northern and Western Beltway to transport spent nuclear fuel and high-level radioactive waste. The distance and population density by county was obtained from Geographical Information System data for the State of Nevada using 1990 Census data. The population density data was escalated to 2035.

Figure J-10 shows the routes in Nevada that legal-weight trucks would use unless the State designated alternative or additional preferred routes. The figure shows estimates for the number of legal-weight truck shipments that would travel on each route segment for the mostly legal-weight truck and mostly rail transportation scenarios. The inset on Figure J-10 shows the Las Vegas Beltway and the routes DOE anticipates legal-weight trucks traveling to the repository would use.

J.3.1.2 Highway and Rail Routes in Nevada for Transporting Rail Casks

The rail and heavy-haul truck implementing alternatives for transportation in Nevada include five possible rail corridors and five possible routes for heavy-haul trucks; the corridors and routes for these implementing alternatives are shown in Figures J-11 and J-12. These figures also show the estimated number of rail shipments that would enter the State on mainline railroads. These numbers indicate shipments that would arrive from the direction of the bordering state for each of the implementing alternatives for the mostly rail transportation scenario.

Table J-33 lists the total length and cumulative distance in rural, suburban, and urban population zones and the population density in each population zone in the State of Nevada used to analyze impacts of the implementing alternatives. Table J-34 lists the cumulative distance in rural, suburban, and urban population zones and the population density in each population zone for existing commercial rail lines in Nevada. DOE based the estimated population that would live along each branch rail line on population densities in census blocks along the candidate rail corridors in Nevada. The populations are based on 1990 Census data escalated to 2035. For this analysis, the ending rail nodes in Nevada for commercial rail lines would be origins for the rail and heavy-haul truck alternatives listed in Table J-33. Table J-35 lists the total population that lives within 800 meters (0.5 mile) of rail lines in Nevada.

Nevada Heavy-Haul Truck Scenario

Tables J-36 through J-40 summarize the road upgrades for each of the five possible routes for heavy-haul trucks that DOE estimates would be needed before routine use of a route to ship casks containing spent nuclear fuel and high-level radioactive waste.

Nevada Rail Corridors

Under the mostly rail scenario, DOE could construct and operate a branch rail line in Nevada. Based on the studies listed below, DOE has narrowed its consideration for a new branch rail line to five potential rail corridors—Carlin, Caliente, Caliente-Chalk Mountain, Jean, and Valley Modified. DOE identified the five rail corridors through a process of screening potential rail alignments that it had studied in past years. Several studies evaluated rail transportation.

- The *Feasibility Study for Transportation Facilities to Nevada Test Site* study (DIRS 104777-Holmes & Narver 1962, all) determined the technical and economic feasibility of constructing and operating a railroad from Las Vegas to Mercury.

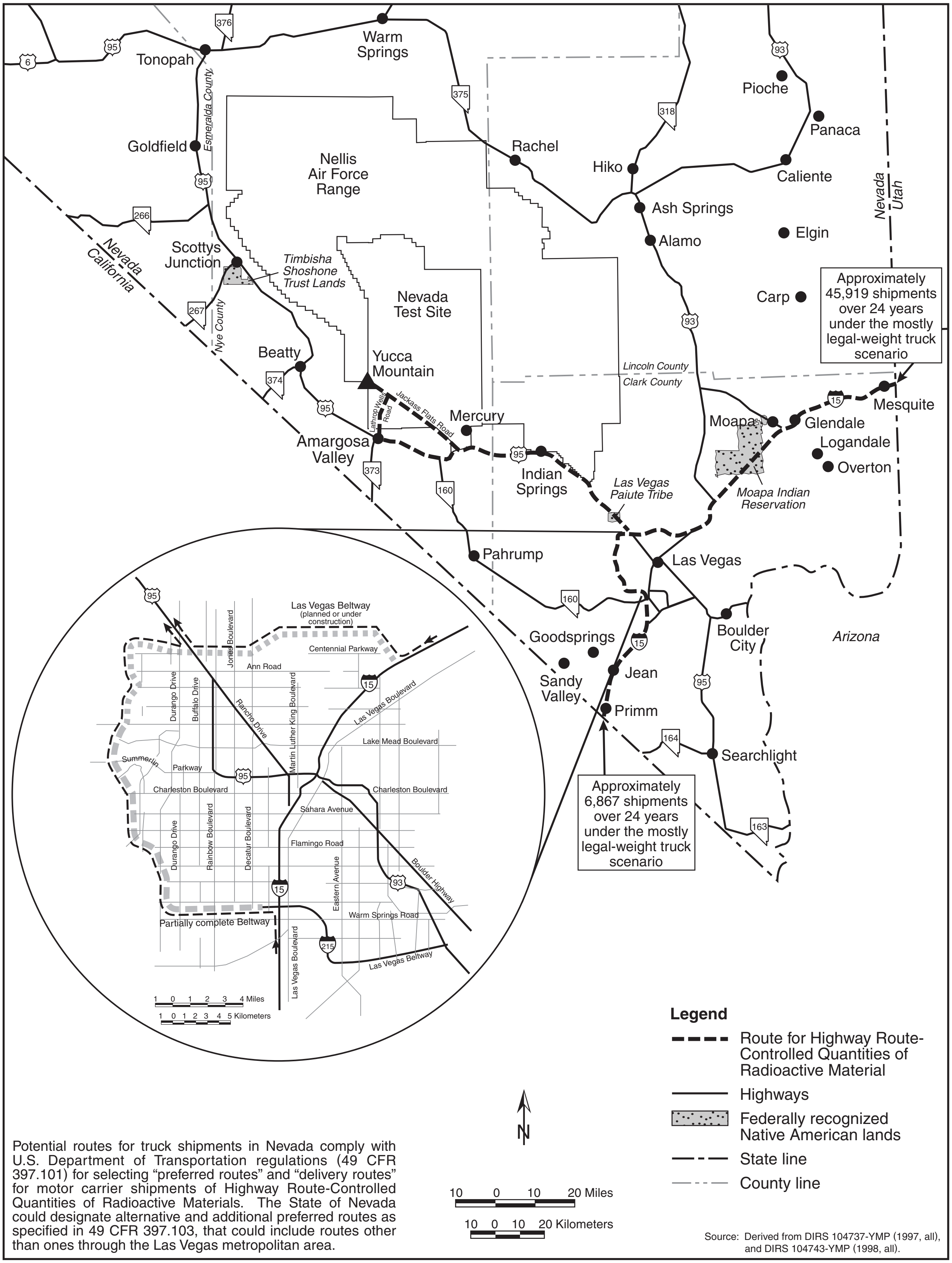

Figure J-10. Potential Nevada routes for legal-weight trucks and estimated number of shipments.

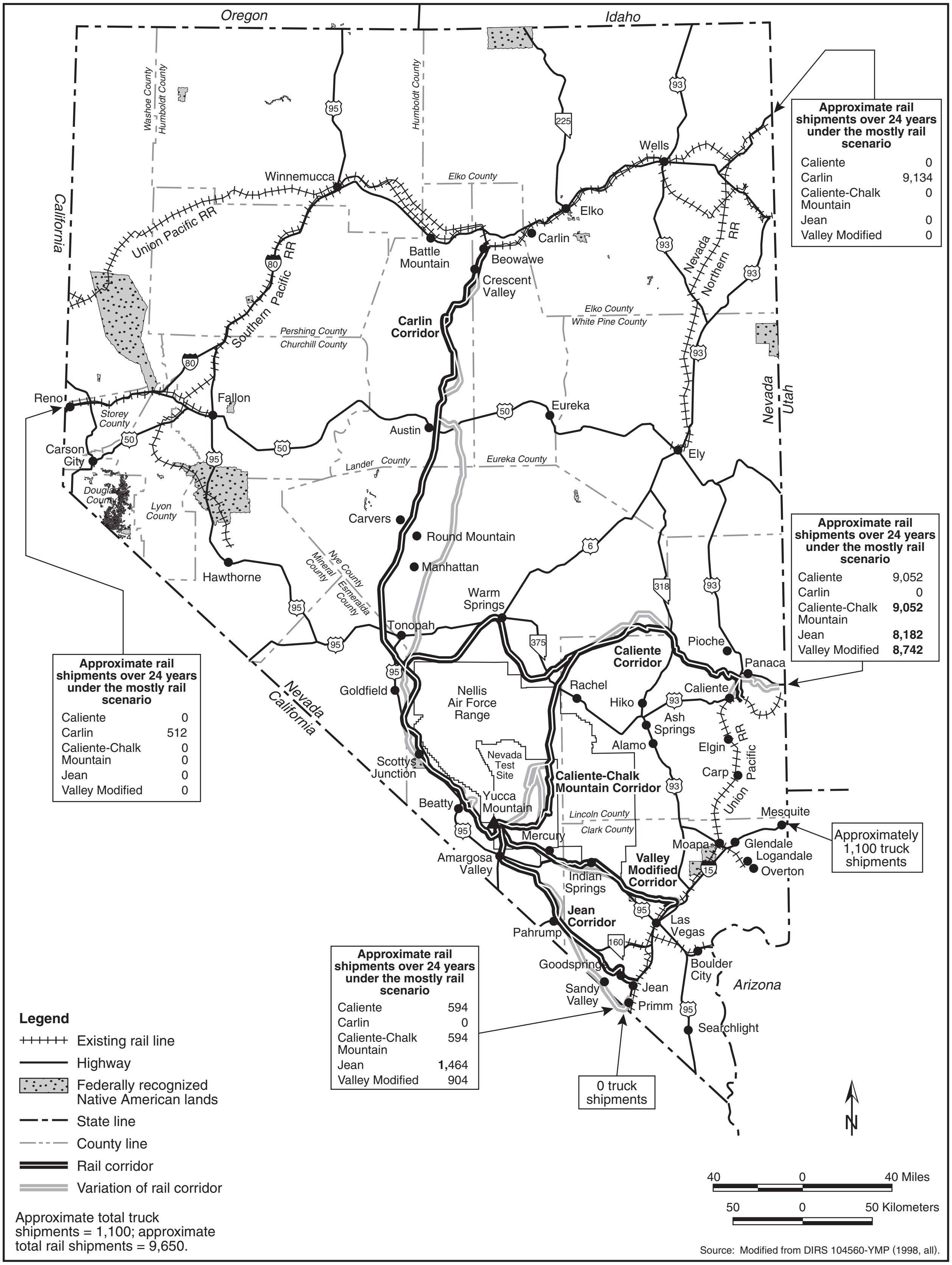

Figure J-11. Potential Nevada rail routes to Yucca Mountain and estimated number of shipments.

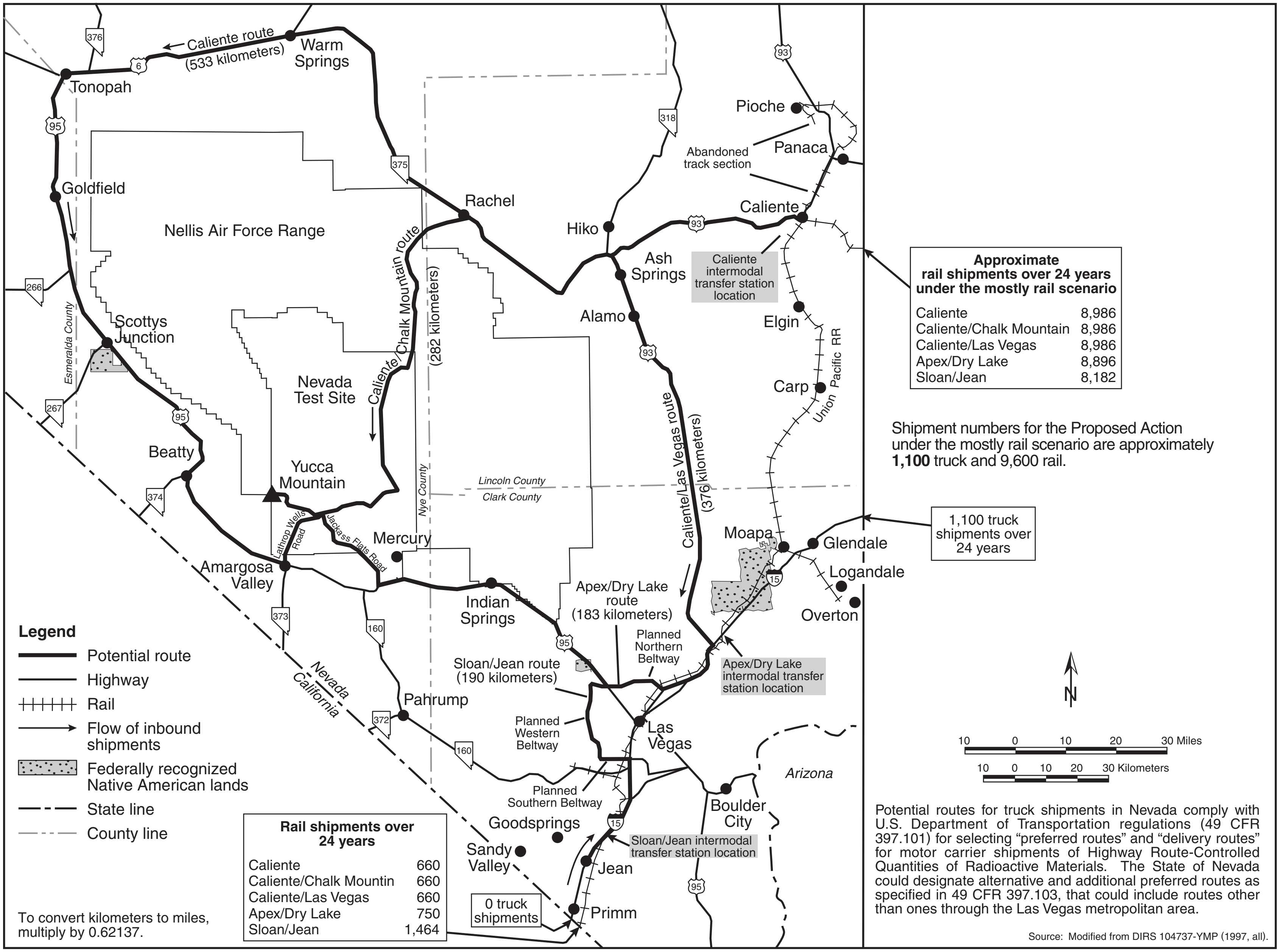

Figure J-12. Potential Nevada routes for heavy-haul trucks and estimated number of shipments.

Table J-33. Routing characteristics in Nevada for legal-weight truck, rail and heavy-haul truck implementing alternatives.

Route	County	Distance (kilometers)[a]				Population density (persons per square kilometer)		
		Urban	Suburban	Rural	Total	Urban	Suburban	Rural
Legal-weight truck route in Nevada using the Las Vegas Beltway								
Northern route	Clark	0.0	19.9	187.5	207.4	0.0	577	10.6
Northern route	Nye	0.0	0.0	64.7	64.7	0.0	0.0	0.0
Southern route	Clark	0.0	41.9	126.9	168.8	0.0	577	3.5
Southern route	Nye	0.0	0.0	64.7	64.7	0.0	0.0	0.0
Rail alternatives								
Caliente-Chalk Mountain	Lincoln	0.0	0.0	158.0	158.0	0.0	0.0	0.0
Caliente-Chalk Mountain	Nye	0.0	0.0	188.0	188.0	0.0	0.0	0.0
Caliente	Esmeralda	0.0	0.0	4.0	4.0	0.0	0.0	0.3
Caliente	Lincoln	0.0	0.0	148.5	148.5	0.0	0.0	0.0
Caliente	Nye	0.0	0.0	360.8	360.8	0.0	0.0	0.1
Carlin	Eureka	0.0	0.0	29.8	29.8	0.0	0.0	0.1
Carlin	Lander	0.0	0.0	158.7	158.7	0.0	0.0	0.0
Carlin	Esmeralda	0.0	0.0	41.0	41.0	0.0	0.0	0.4
Carlin	Nye	0.0	0.0	291.5	291.5	0.0	0.0	0.6
Jean	Clark	0.0	0.0	82.4	82.4	0.0	0.0	0.8
Jean	Nye	0.0	0.0	98.2	98.2	0.0	0.0	0.2
Apex	Clark	0.0	0.0	99.5	99.5	0.0	0.0	0.1
Apex	Nye	0.0	0.0	59.2	59.2	0.0	0.0	0.0
Heavy-haul alternatives								
Apex/Dry Lake	Clark	0.0	19.9	104.0	123.9	0.0	577	2.9
Apex/Dry Lake	Nye	0.0	0.0	59.4	59.4	0.0	0.0	0.001
Caliente	Esmeralda	0.0	0.0	71.6	71.6	0.0	0.0	2.0
Caliente	Lincoln	0.0	0.0	148.5	148.5	0.0	0.0	0.8
Caliente	Nye	0.0	4.7	308.5	313.2	0.0	261	0.7
Caliente/Las Vegas	Clark	0.0	19.9	147.3	167.2	0.0	577	2.1
Caliente/Las Vegas	Lincoln	0.0	0.0	149.7	149.7	0.0	0.0	0.8
Caliente/Las Vegas	Nye	0.0	0.0	59.4	59.4	0.0	0.0	0.001
Caliente/Chalk Mountain	Lincoln	0.0	0.0	146.9	146.9	0.0	0.0	0.9
Caliente/Chalk Mountain	Nye	0.0	0.0	135.3	135.3	0.0	0.0	0.0
Jean/Sloan	Clark	0.0	41.9	88.6	130.5	0.0	577	5.3
Jean/Sloan	Nye	0.0	0.0	59.4	59.4	0.0	0.0	0.0006

a. To convert kilometers to miles, multiply by 0.62137.

- The *Preliminary Rail Access Study* (DIRS 104792-YMP 1990, all) identified 13 and evaluated 10 rail corridor alignment options. This study recommended the Carlin, Caliente, and Jean Corridors for detailed evaluation.

- *The Nevada Railroad System: Physical, Operational, and Accident Characteristics* (DIRS 104735-YMP 1991, all) described the operational and physical characteristics of the current Nevada railroad system.

- The *High Speed Surface Transportation Between Las Vegas and the Nevada Test Site (NTS)* report (DIRS 104786-Cook 1994, all) explored the rationale for a potential high-speed rail corridor between Las Vegas and the Nevada Test Site to accommodate personnel.

- The *Nevada Potential Repository Preliminary Transportation Strategy, Study 1* (DIRS 104795-CRWMS M&O 1995, all), reevaluated 13 previously identified rail routes and evaluated a new route called the Valley Modified route. This study recommended four rail corridors for detailed evaluation—Caliente, Carlin, Jean, and Valley Modified.

Table J-34. Routing characteristics in Nevada for existing commercial rail lines.

End node	Route	County	Distance (kilometers)[a]				Population density (persons per square kilometer)		
			Urban	Suburban	Rural	Total	Urban	Suburban	Rural
Beowawe	NV existing rail via Utah	Eureka	0.0	0.0	31.5	31.5	0.0	0.0	0.1
Beowawe	NV existing rail via Utah	Elko	0.0	11.3	218.1	229.3	0.0	463.4	2.0
Beowawe	NV existing rail via Reno	Humboldt	0.0	6.4	103.8	110.2	0.0	431.4	5.5
Beowawe	NV existing rail via Reno	Pershing	0.0	3.2	117.8	121.0	0.0	377.0	2.6
Beowawe	NV existing rail via Reno	Lander	0.0	3.2	41.0	44.3	0.0	577.3	3.5
Beowawe	NV existing rail via Reno	Eureka	0.0	0.0	22.7	22.7	0.0	0.0	0.1
Beowawe	NV existing rail via Reno	Washoe	3.2	23.3	26.8	53.4	1,953.2	517.6	14.9
Beowawe	NV existing rail via Reno	Churchill	0.0	0.0	66.8	66.8	0.0	0.0	0.0
Beowawe	NV existing rail via Reno	Storey	0.0	2.4	18.0	20.4	0.0	199.9	8.7
Beowawe	NV existing rail via Reno	Lyon	0.0	3.2	14.7	18.0	0.0	586.9	12.9
Jean	NV existing rail Jean from south	Clark	0.0	0.0	41.7	41.7	0.0	0.0	1.0
Jean	NV existing rail Jean from north	Clark	3.2	17.7	110.0	130.9	1,879.6	750.6	0.8
Jean	NV existing rail Jean from north	Lincoln	0.0	1.6	167.8	169.4	0.0	294.3	0.8
Apex	NV existing rail Apex from north	Lincoln	0.0	1.6	167.8	169.4	0.0	294.3	0.8
Apex	NV existing rail Apex from north	Clark	0.0	0.0	50.8	50.8	0.0	0.0	2.0
Apex	NV existing rail Apex from south	Clark	3.2	17.7	100.9	121.8	1,879.6	750.6	1.4
Caliente	NV existing routing to Caliente from north	Lincoln	0.0	0.0	64.7	64.7	0.0	0.0	0.8
Caliente	NV existing routing to Caliente from south	Clark	3.2	17.7	151.7	172.6	1,879.6	750.6	1.6
Caliente	NV existing routing to Caliente from south	Lincoln	0.0	1.6	103.1	104.7	0.0	294.3	0.9
Eccles	NV existing routing to Eccles from north	Lincoln	0.0	0.0	56.3	56.3	0.0	0.0	0.0
Eccles	NV existing routing to Eccles from south	Clark	3.2	17.7	151.7	172.6	1,879.6	750.6	1.6
Eccles	NV existing routing to Eccles from south	Lincoln	0.0	1.6	111.4	113.1	0.0	294.3	1.3
Dry Lake	NV existing routing to Dry Lake from north	Lincoln	0.0	1.6	167.8	169.4	0.0	294.3	0.8
Dry Lake	NV existing routing to Dry Lake from north	Clark	0.0	0.0	50.8	50.8	0.0	0.0	2.0
Dry Lake	NV existing routing to Dry Lake from south	Clark	3.2	17.7	100.9	121.8	1,879.6	750.6	1.4

a. To convert kilometers to miles, multiply by 0.62157.

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Table J-35. Populations in Nevada within 800 meters (0.5 mile) of routes.[a,b]

Transportation scenario	Population 2035 projections
Legal-weight truck routes[a]	190,000/300,000
Rail routes Nevada border to branch rail line[b]	
Caliente (from the North – UT)	110
Caliente (from the South – CA)	115,000
Beowawe (from the east – UT)	21,000
Beowawe (from the west – CA)	98,000
Eccles (from the North – UT)	3
Eccles (from the south – CA)	115,000
Jean (from the North – UT)	114,000
Jean (from the South – CA)	250
Dry Lake (from the North – UT)	1,900
Dry Lake (from the South – CA)	113,000
Branch rail lines	
Caliente	140
Carlin	1,280
Caliente-Chalk Mountain	31
Jean	520
Valley Modified	75
Heavy-haul routes	
Caliente	11,000
Caliente/Chalk Mountain	740
Caliente/Las Vegas	187,000
Sloan/Jean	390,000
Apex/Dry Lake	186,000

a. The estimated populations represent using the route from the north and from the south, respectively.
b. The analysis assumed there would be an average of 800,000 visitors per day to Las Vegas.

Table J-36. Potential road upgrades for Caliente route.[a]

Route	Upgrades
Intermodal transfer station to U.S. 93	Pave existing gravel road.
U.S. 93 to State Route 375	Asphalt overlay on existing pavement, truck lanes where grade is greater than 4 percent (minimum distance of 460 meters[b] per lane), turnout lanes every 32 kilometers[c] (distance of 305 meters per lane), widen road.
State Route 375 to U.S. 6	Remove existing pavement, increase road base and overlay to remove frost restrictions, truck lanes where grade is greater than 4 degrees (minimum distance of 460 meters per lane), turnout lanes every 32 kilometers (distance of 305 meters per lane), widen road.
U.S. 6 to U.S. 95	Same as State Route 375 to U.S. 6.
U.S. 95 to Lathrop Wells Road	Remove existing pavement on frost restricted portion, increase base and overlay to remove frost restrictions, turnout lanes every 8 kilometers (distance of 305 meters per lane), construct bypass around intersection at Beatty, bridge upgrade near Beatty.
Lathrop Wells Road to Yucca Mountain site	Asphalt overlay on existing roads.

a. Source: DIRS 154448-CRWMS M&O (1998, all).
b. To convert meters to feet, multiply by 3.2808.
c. To convert kilometers to miles, multiply by 0.62137.

Table J-37. Potential road upgrades for Caliente/Chalk Mountain route.[a]

Route	Upgrades
Intermodal transfer station to U.S. 93	Pave existing gravel road.
U.S. 93 to State Route 375	Asphalt overlay on existing pavement, truck lanes where grade is greater than 4 percent (minimum distance of 460 meters[b] per lane), turnout lanes every 32 kilometers[c] (distance of 305 meters per lane), widen road
State Route 375 to Rachel	Remove existing pavement, increase road base and overlay to remove frost restrictions, turnout lanes every 32 kilometers (distance of 305 meters per lane), widen road.
Rachel to Nellis Air Force Range[d]	Pave existing gravel road.
Nellis Air Force Range Roads	Rebuild existing road.
Nevada Test Site Roads	Asphalt overlay on existing roads.

a. Source: DIRS 155436-CRWMS M&O (1997, all).
b. To convert meters to feet, multiply by 3.2808.
c. To convert kilometers to miles, multiply by 0.62137.
d. Also known as the Nevada Test and Training Range.

Table J-38. Potential road upgrades for Caliente/Las Vegas route.[a]

Route	Upgrades
Intermodal transfer station to U.S. 93	Pave existing gravel road.
U.S. 93 to Interstate 15	Asphalt overlay on existing pavement, truck lanes where grade is greater than 4 percent (minimum distance 460 meters[b] per lane), turnout lanes every 32 kilometers[c] (distance of 305 meters per lane), widen road, rebuild Interstate 15 interchange.
Interstate 15 to U.S. 95	Increase existing two-lane Las Vegas Beltway to four lanes, asphalt overlay on U.S. 95.
U.S. 95 to Mercury	Asphalt overlay on U.S. 95.
Mercury Exit to Yucca Mountain site	Asphalt overlay on Jackass Flats Road, rebuild road when required.

a. Source: DIRS 154448-CRWMS M&O (1998, all).
b. To convert meters to feet, multiply by 3.2808.
c. To convert kilometers to miles, multiply by 0.62137.

Table J-39. Potential road upgrades for Apex/Dry Lake route.[a]

Route	Upgrades
Intermodal transfer station to Interstate 15	Rebuild frontage road to U.S. 93. Rebuild U.S. 93/Interstate 15 interchange.
Interstate 15 to U.S. 95	Increase existing two-lane Las Vegas Beltway to four lanes.
U.S. 95 to Mercury Exit	Asphalt overlay on U.S. 95.
Mercury Exit to Yucca Mountain site	Asphalt overlay on Jackass Flats Road, rebuild road when required.

a. Source: DIRS 154448-CRWMS M&O (1998, all).

Table J-40. Potential road upgrades for Sloan/Jean route.[a]

Route	Upgrades
Intermodal transfer station to Interstate 15	Overlay and widen existing road to Interstate 15 interchange, rebuild Interstate 15 interchange.
Interstate 15 to U.S. 95	Increase existing two-lane Las Vegas Beltway to four lanes.
U.S. 95 to Mercury Exit	Asphalt overlay on U.S. 95.
Mercury Exit to Yucca Mountain site	Asphalt overlay on Jackass Flats Road, rebuild road when required.

a. Source: DIRS 154448-CRWMS M&O (1998, all).

- The *Nevada Potential Repository Preliminary Transportation Strategy*, *Study 2* (DIRS 101214-CRWMS M&O 1996, all), further refined the analyses of potential rail corridor alignments presented in Study 1.

Public comments submitted to DOE during hearings on the scope of this environmental impact statement resulted in addition of a fifth corridor—Caliente-Chalk Mountain.

DOE has identified 0.4-kilometer (0.25-mile)-wide corridors along each route within which it would need to obtain a right-of-way to construct a rail line and an associated access road. A corridor defines the boundaries of the route by identifying an established "zone" for the location of the railroad. For this analysis, DOE identified a single alignment for each of the corridors. These single alignments are representative of the range of alignments that DOE has considered for the corridors from engineering design and construction viewpoints. The following paragraphs describe the alignments that have been identified for the corridors. Before siting a branch rail line, DOE would conduct engineering studies in each corridor to determine a specific alignment for the roadbed, track, and right-of-way for a branch rail line.

Caliente Corridor Implementing Alternative. The Caliente Corridor originates at an existing siding to the Union Pacific mainline railroad near Caliente, Nevada. The Caliente and Carlin Corridors converge near the northwest boundary of the Nellis Air Force Range (also known as the Nevada Test and Training Range). Past this point, they are identical. The Caliente Corridor is 513 kilometers (320 miles) long from the Union Pacific line connection to the Yucca Mountain site. Table J-41 lists possible alignment variations for this corridor.

Carlin Corridor Implementing Alternative. The Carlin Corridor originates at the Union Pacific main line railroad near Beowawe in north-central Nevada. The corridor is about 520 kilometers (331 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site. Table J-42 lists possible variations in the alignment of this corridor.

Caliente-Chalk Mountain Corridor Implementing Alternative. The Caliente-Chalk Mountain Corridor is identical to the Caliente Corridor until it approaches the northern boundary of the Nellis Air Force Range (also known as the Nevada Test and Training Range). At this point the Caliente-Chalk Mountain Corridor turns south through the Nellis Air Force Range and the Nevada Test Site to the Yucca Mountain site. The corridor is 345 kilometers (214 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain site. Table J-43 lists possible alignment variations for this corridor.

Jean Corridor Implementing Alternative. The Jean Corridor originates at the existing Union Pacific mainline railroad near Jean, Nevada. The corridor is 181 kilometers (112 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain site. Table J-44 lists possible variations for this corridor.

Valley Modified Corridor Implementing Alternative. The Valley Modified Corridor originates at an existing rail siding off the Union Pacific mainline railroad northeast of Las Vegas. The corridor is about 159 kilometers (98 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site. Table J-45 lists the possible variations in alignment for this corridor.

Land Use Conflicts Along Potential Rail Corridors in Nevada

Figures J-13 through J-20 show potential land-use conflicts along candidate rail corridors for construction of a branch rail line in Nevada.

Table J-41. Possible variations of the Caliente Corridor.[a]

Variation	Description[b]
Eccles Option	Included in corridor description. Crosses private land and BLM lands. No ROWs crossed.
Caliente Option[c]	Connects with Union Pacific line at existing siding in Town of Caliente. Crosses approximately twice the amount of private lands than the primary alignment. Crosses 2 ROWs – 1 telephone and 1 road (U.S. 93).
Crestline Option[c]	Connects with Union Pacific line near east end of existing siding at Crestline. Crosses approximately twice the private land as the corridor. Crosses 2 ROWs – 1 telephone and 1 road.
White River Alternate[c]	Avoids potential conflict of the corridor with Weepah Spring Wilderness Study Area. Would cross approximately 0.012 square kilometer (3 acres) of private land.
Garden Valley Alternate[c]	Puts more distance between corridor and private lands in Garden Valley and Coal Valley. Crosses 2 road ROWs and 2 pipelone ROWs. Crosses approximately same amount of private land as corridor.
Mud Lake Alternate[c]	Travels farther from west edge of Mud Lake, which has known important archaeological sites. Mud Lake contains 4 possible route variations that are located on BLM lands.
Goldfield Alternate[c]	Avoids crossing Nellis Air Force Range boundary near Goldfield, avoiding potential land-use conflicts with Air Force. Crosses mostly BLM lands but also crosses approximately 0.75 square kilometer of private lands.
Bonnie Claire Alternate[c]	Avoids crossing Nellis Air Force Range boundary near Scottys Junction, avoiding potential land-use conflicts with Air Force. Crosses mostly BLM lands but also crosses approximately 0.43 square kilometer of private property. Crosses a BLM utility corridor, 3 road ROWs, 2 telephone ROWs, and 4 power ROWs. Crosses Timbisha Shoshone trust lands parcel.
Oasis Valley Alternate[c]	Enables flexibility in crossing environmentally sensitive Oasis Valley area. If DOE selected a route through this area, further studies would ensure small environmental impacts.
Beatty Wash Alternate[c]	Provides alternate corridor through Beatty Wash that is longer, but requires less severe earthwork than the corridor.

a. Source: DIRS 131242-CRWMS M&O (1997, all).
b. Abbreviations: BLM = Bureau of Land Management; ROW = right-of-way.
c. Common with Carlin Corridor.

Minority Populations Along Potential Transportation Routes in Nevada

Census Bureau information available to DOE and considered in this EIS includes geographical identification of census blocks containing minority populations within the environmental justice definition used by DOE (that is, a minority population is one in which the percent of the population of an area's racial or ethnic minority is 44.8 percentage points or more of the total population).

There is no corresponding census block information for low-income populations. To provide the information on minority census blocks to decisionmakers and the public, DOE has prepared a set of maps (Figures J-21 through J-30) showing the location of minority census blocks near potential transportation corridors. The maps depict 6-kilometer bands on each side of each corridor.

Darkly shaded areas represent minority blocks in or near the 6-kilometer bands. Lightly shaded areas represent the balance of land within the 6-kilometer bands. Dotted areas of intermediate shading represent Native American lands. All lands shown on maps and not represented as minority block or Native American is land that does not have a minority population within the definition used in this EIS (see Chapter 3, Section 3.1.13.1) to consider environmental justice concerns.

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Table J-42. Possible variations of the Carlin Corridor.[a]

Variation	Description[b]
Crescent Valley Alternate	Diverges from the corridor near Cortez Mining Operation where it would cross a proposed pipeline ROW that would supply water to the Dean Ranch; travels through nonagricultural lands adjacent to alkali flats but would affect larger area of private land. Crosses 2 existing roads, one of which has an established ROW.
Wood Spring Canyon Alternate	Diverges from the corridor and use continuous 2-percent grade to descend from Dry Canyon Summit in Toiyabe range; is shorter than the corridor segment but would have steeper grade. Continues on BLM land.
Rye Patch Alternate	Travels through Rye Patch Canyon, which has springs, riparian areas, and game habitats; diverts from the corridor, maintaining distance of 420 meters[c] from Rye Patch Spring and at least 360 meters from riparian areas throughout Rye Patch Canyon, except at crossing of riparian area near south end of canyon; avoids game habitat (sage grouse strutting area). Passes through a BLM utility corridor, one road and one road ROW (U.S. 50).
Steiner Creek Alternate	Diverges from the corridor at north end of Rye Patch Canyon. Avoids crossing private lands, two known hawk-nesting areas, and important game habitat (sage grouse strutting area) in the corridor. Passes close to Steiner Creek WSA.
Smoky Valley Option	Travels through less populated valley than Monitor Valley Option. Crosses more ROWs than Monitor Valley Option. Passes through all BLM land until route enters NTS. Passes through a Desert Land Entry area.
Monitor Valley Option	Travels through less populated Monitor Valley (in comparison to Big Smoky Valley). Crosses the Monitor, Ralston, and Potts grazing allotments. Also passes through 2 areas with application to Desert Land Entry Program. Passes 2 road ROWs, 1 telephone, 1 pipeline, and 3 powerline ROWs.
Mud Lake Alternate[d]	Travels farther from west edge of Mud Lake, which has known important archaeological sites. Mud Lake contains 4 possible route variations that are located on BLM lands.
Goldfield Alternate[d]	Avoids crossing Nellis Air Force Range boundary near Goldfield, avoiding potential land-use conflicts with Air Force. Crosses mostly BLM lands but also crosses approximately 0.75 square kilometer[e] of private lands.
Bonnie Claire Alternate[d]	Avoids crossing Nellis Air Force Range boundary near Scottys Junction, avoiding potential land-use conflicts with Air Force. Crosses mostly BLM lands but also crosses approximately 0.43 square kilometer of private property. Crosses a BLM utility corridor, 3 road ROWs, 2 telephone ROWs, and 4 power ROWs. Crosses Timbisha Shoshone trust lands parcel.
Oasis Valley Alternate[d]	Enables flexibility in crossing environmentally sensitive Oasis Valley area. If DOE selected a route through this area, further studies would ensure small environmental impacts.
Beatty Wash Alternate[d]	Provides alternate corridor through Beatty Wash that is longer, but requires less severe earthwork than the corridor.

a. Source: DIRS 131242-CRWMS M&O (1997, all).
b. Abbreviations: BLM = Bureau of Land Management; NTS = Nevada Test Site; ROW = right-of-way; WSA = Wilderness Study Area.
c. To convert meters to feet, multiply by 3.2808.
d. Common with Caliente corridor.
e. To convert square kilometers to acres, multiply by 247.1.

Although the populations of most census blocks are small, the size of many blocks is large. The depiction of minority blocks does not show the location of any residences within blocks. Census bureau data did not include residential locations. No inference should be drawn from these maps as to the location of residences within depicted areas.

Table J-43. Possible variations of the Caliente-Chalk Mountain Corridor.

Variation	Description
Caliente Option	Same as Table J-41. Connects with Union Pacific Line at existing siding in Town of Caliente.
Eccles Option	Same as Table J-41.
Orange Blossom Option	Crosses Nevada Test Site land. Bypasses roads and facilities.
Crestline Option	Same as Table J-41. Connects with Union Pacific line near east end of existing siding at Caliente.
White River Alternate	Same as Table J-41. Avoids potential conflict with Weepah Springs Wilderness Study Area.
Garden Valley Alternate	Same as Table J-41. Puts more distance between rail corridor and private lands in Garden Valley and Coal Valley.
Mercury Highway Option	To provide flexibility in choosing path through Nevada Test Site, travels north through center of Nevada Test Site. Requires slightly less land [approximately 0.2 square kilometers (50 acres)] than corridor. Crosses Mercury Highway.
Topopah Option	To provide flexibility in choosing path through Nevada Test Site, travels north along western boundary of Nevada Test Site.
Mine Mountain Alternate	Provides flexibility in minimizing impacts to local archaeological sites.
Area 4 Alternate	Provides flexibility in choosing path through Nevada Test Site. Crosses Mercury Highway. Requires slightly less land.

a. Source: DIRS 155628-CRWMS M&O (1997, all).

J.3.1.3 Sensitivity of Analysis Results to Routing Assumptions

In addition to analyzing the impacts of using highway routes that would meet U.S. Department of Transportation requirements for transporting spent nuclear fuel, DOE evaluated how the estimated impacts would differ if legal-weight trucks used other routes in Nevada. Six other routes identified in a 1989 study by the Nevada Department of Transportation (DIRS 103072-Ardila-Coulson 1989, pp. 36 and 45) were selected for this analysis. The Nevada Department of Transportation study described the routes as follows:

Route A. Minimum distance and minimum accident rate.
South on U.S. 93A, south on U.S. 93, west on U.S. 6, south on Nevada 318, south on U.S. 93, south on I-15, west on Craig Road, north on U.S. 95

Route B. Minimum population density and minimum truck accident rate.
Both of these two routes use the U.S. 6 truck bypass in Ely.

Alternative route possibilities were identified between I-15 at Baker, California and I-40 at Needles, California to Mercury. These alternative routes depend upon the use of U.S. 95 in California, California 127 and the Nipton Road.

Route C. From Baker with California 127.
North on California 127, north on Nevada 373, south on U.S. 95

Route D. From Baker without California 127.
North on I-15, west on Nevada 160, south on U.S. 95

Route E. From Needles with U.S. 95, California 127, and the Nipton Road.
North on U.S. 95, west on Nevada 164, west on I-15, north on California 127, north on Nevada 373, south on U.S. 95

Route F. From Needles without California 127 and the Nipton Road.
West on I-40, east on I-15, west on Nevada 160, south on U.S. 95

Table J-44. Possible variations of the Jean Corridor.[a]

Variation	Description[b]
North Pahrump Valley Alternate	Minimizes impacts to approximately 4 kilometers[c] of private land on northeast side of Pahrump. Abuts Toiyabe National Forest and a BLM corridor. Travels within a BLM utility corridor. Crosses approximately twice as much BLM lands as corridor and 0.0999 square kilometer[d] of private land compared to 3.5 square kilometers.
Wilson Pass Option	Crosses 2 pipeline ROWs, 3 road/highway ROWs, 2 powerline ROWs. Enter BLM utility corridor for approximately 46 kilometers. Passes within 1.6 kilometers of Toiyabe National Forest and close to 3 mines. Also passes through BLM Class II visual resource lands.
Stateline Pass Option	Provides option to crossing Spring Mountains at Wilson Pass; diverges from corridor in Pahrump Valley; parallels Nevada-California border, traveling along southwestern edge of Spring Mountains and crossing border twice. Bypasses private land crossed by primary alignment. Origination of option would conflict with the proposed Ivanpah Valley Airport. Crosses 2 pipeline ROWs, 2 road ROWs, 1 powerline, 1 telephone ROW, 1 withdrawal area (unexplained), a BLM utility corridor, and 1 community pit. Passes close to Stateline WSA. Crosses Black Butte and Roach Lake grazing allotments.

a. Source: DIRS 131242-CRWMS M&O (1997, all).
b. Abbreviations: BLM = Bureau of Land Management; ROW = right-of-way; WSA = Wilderness Study Area.
c. To convert kilometers to miles, multiply by 0.62137.
d. To convert square kilometers to acres, multiply by 247.1.

Table J-45. Possible variations of the Valley Modified Corridor.[a]

Variation	Description[b]
Indian Hills Alternate	Avoids entrance to Nellis Air Force Range north of Town of Indian Springs by traveling south of town. U.S. Fish and Wildlife Service land. Crosses 1 road, 2 telephone, and 2 powerline ROWs. Passes almost entirely within BLM utility corridor. Passes through a land withdrawal area.
Sheep Mountain Alternate	Increases distance from private land in Las Vegas and proposed 30-square-kilometer[c] BLM land exchange with city. Crosses small parcels (approximately 0.18 square kilometer) of private land. Crosses 3 powerline ROWs. Passes through Nellis Small Arms Range, Nellis WSAs A, B, and C, the Desert National Wildlife Range, and the Quail Spring WSA.
Valley Connection	Locates transfer operations at Union Pacific Valley Yard rather than Dike siding. Overflights of Dike siding from Nellis Air Force Base could conflict with switching operations. Crosses slightly more private land.

a. Source: DIRS 131242-CRWMS M&O (1997, all).
b. Abbreviations: BLM = Bureau of Land Management; ROW = right-of-way; WSA = Wilderness Study Area.
c. To convert square kilometers to acres, multiply by 247.1.

Table J-46 identifies the sensitivity cases evaluated based on the Nevada Department of Transportation routes. Tables J-47 and J-48 list the range of impacts in Nevada of using these different routes for the mostly legal-weight truck analysis scenario. The tables compare the impacts estimated for the highways identified in the Nevada study to those estimated for shipments that would follow routes allowed by current U.S. Department of Transportation regulations for Highway Route-Controlled Quantities of Radioactive Materials. Because the State of Nevada has not designated alternative or additional preferred routes for use by these shipments, as permitted under U.S. Department of Transportation regulations (49 CFR 397.103), DOE has assumed that shipments of spent nuclear fuel and high-level radioactive waste would enter Nevada on I-15 from either the northeast or southwest. The analysis assumed that shipments traveling on I-15 from the northeast would use the northern Las Vegas Beltway to connect to U.S. 95 and continue to the Nevada Test Site. Shipments from the southwest on I-15 would use the southern and western Las Vegas Beltway to connect to U.S. 95 and continue to the Nevada Test Site.

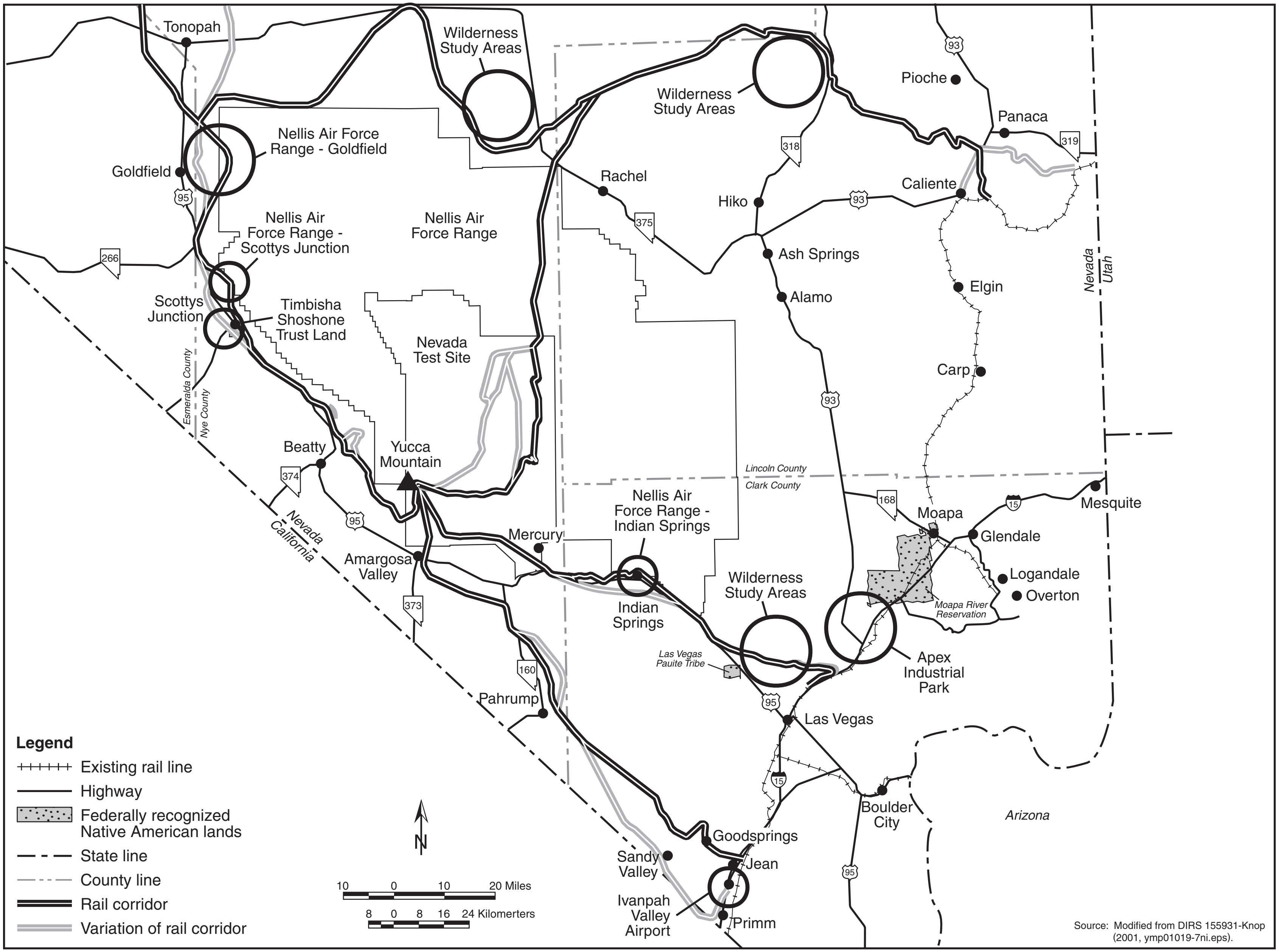

Figure J-13. Land-use conflicts along Nevada rail corridors, overview.

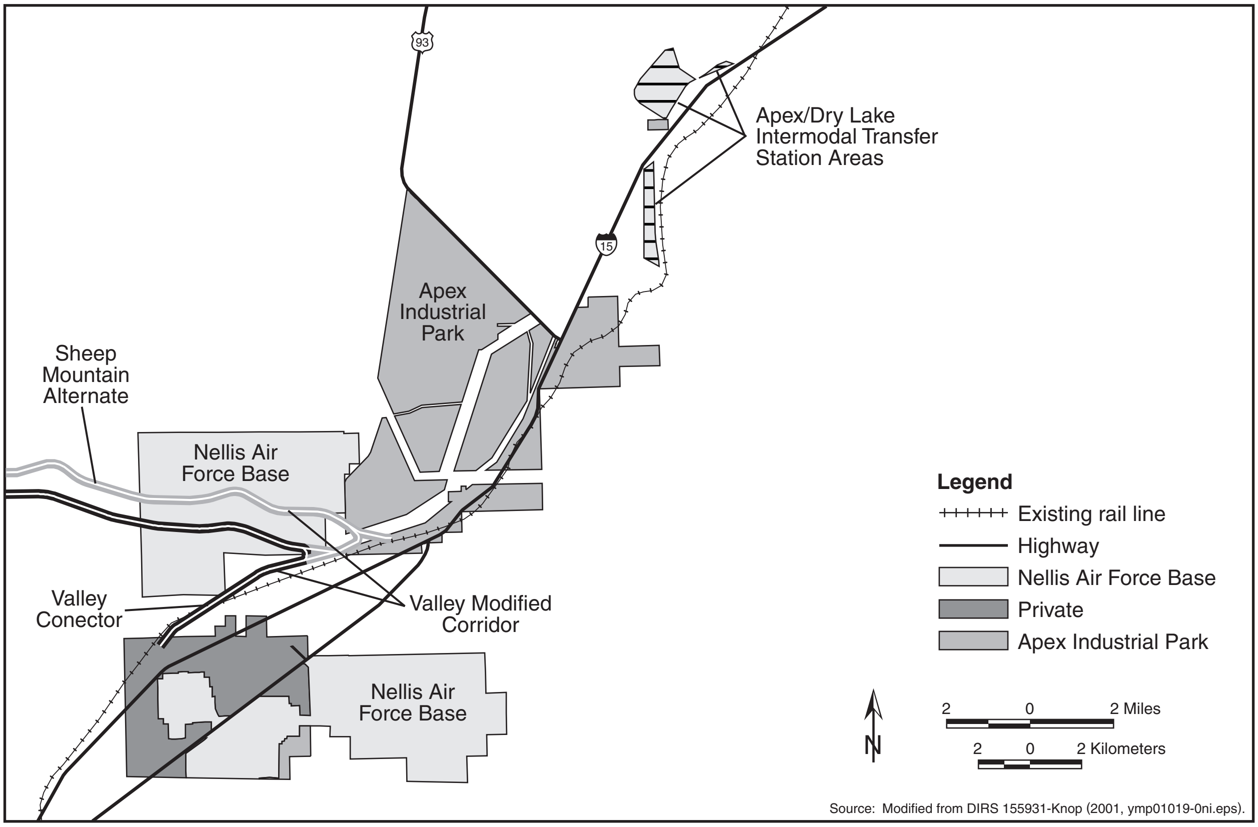

Figure J-14. Land-use conflicts along Nevada rail corridors, Apex Industrial Park.

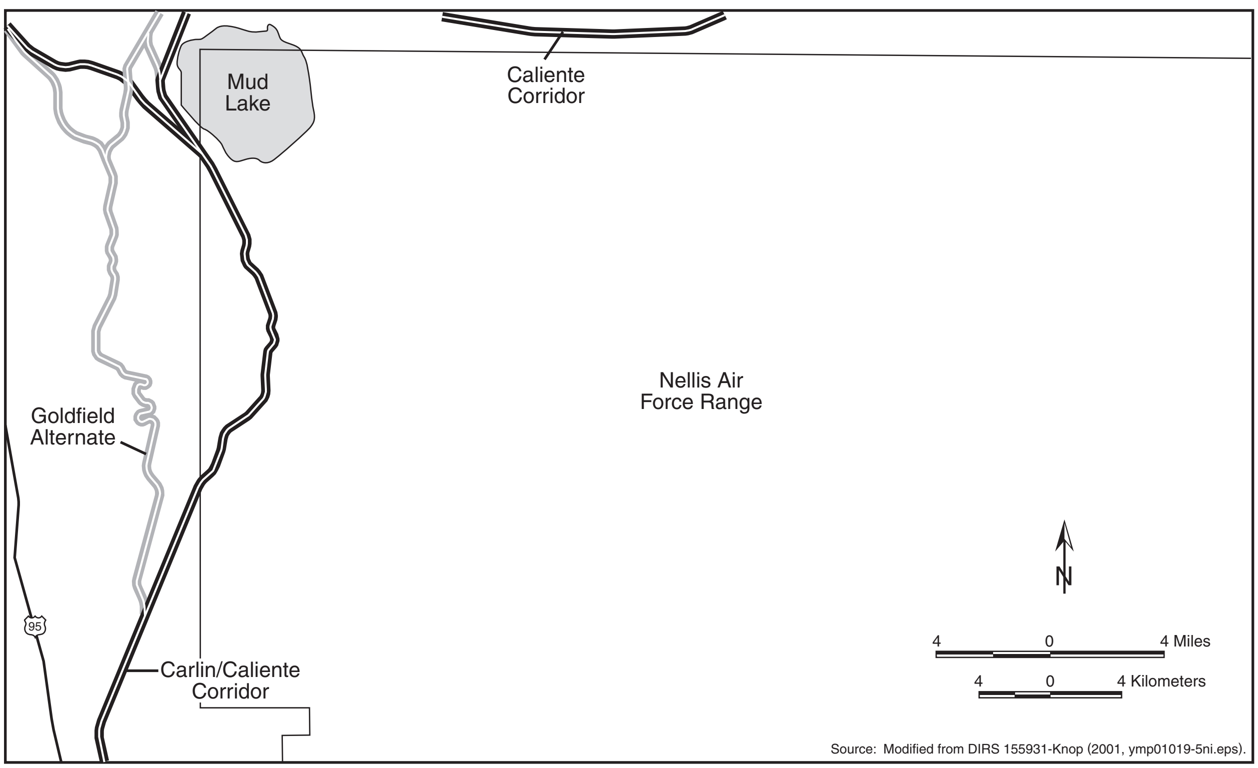

Figure J-15. Land-use conflicts along Nevada rail corridors, Nellis Air Force Range, Goldfield area.

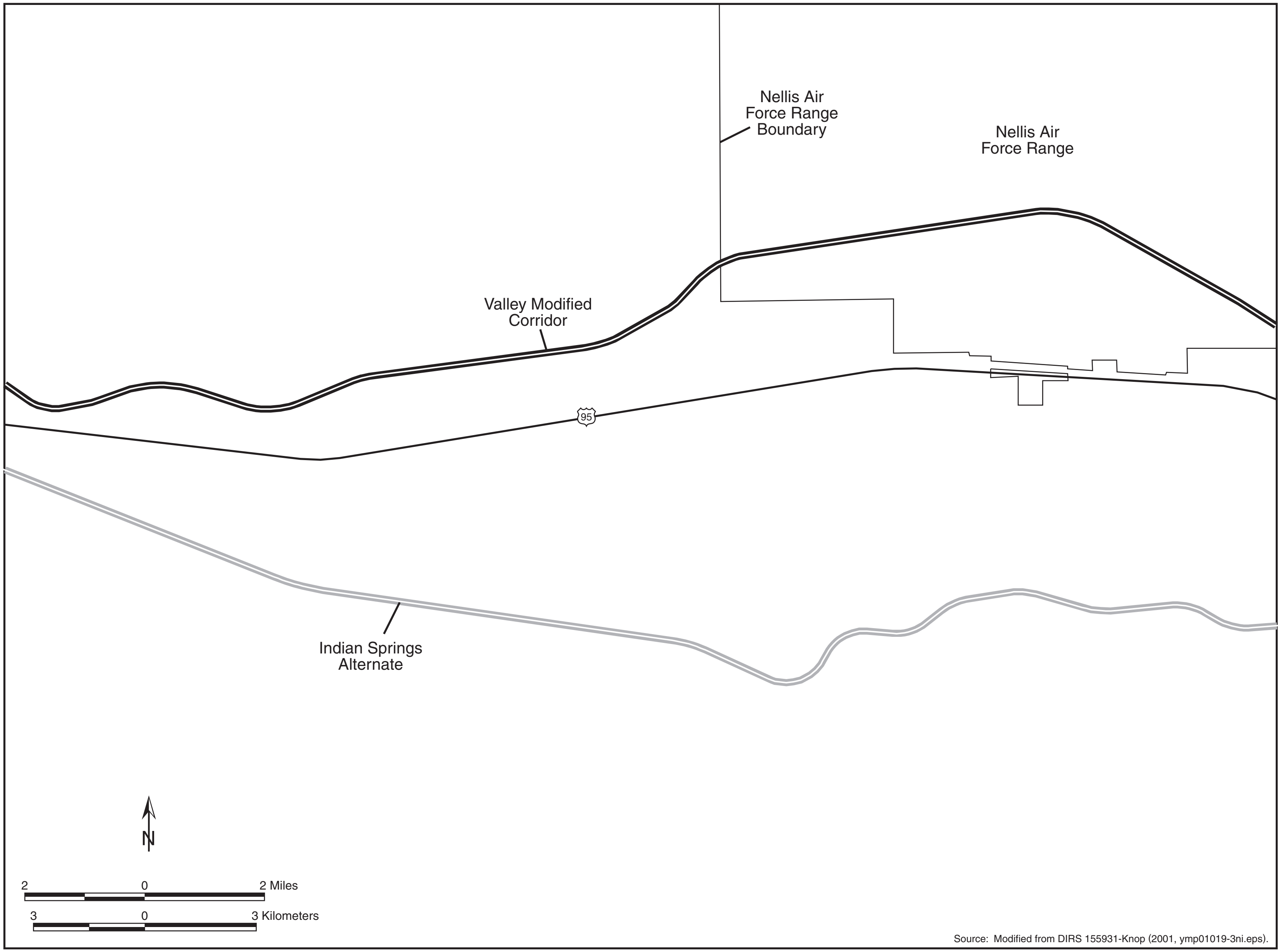

Figure J-16. Land-use conflicts along Nevada rail corridors, Nellis Air Force Range, Indian Springs area.

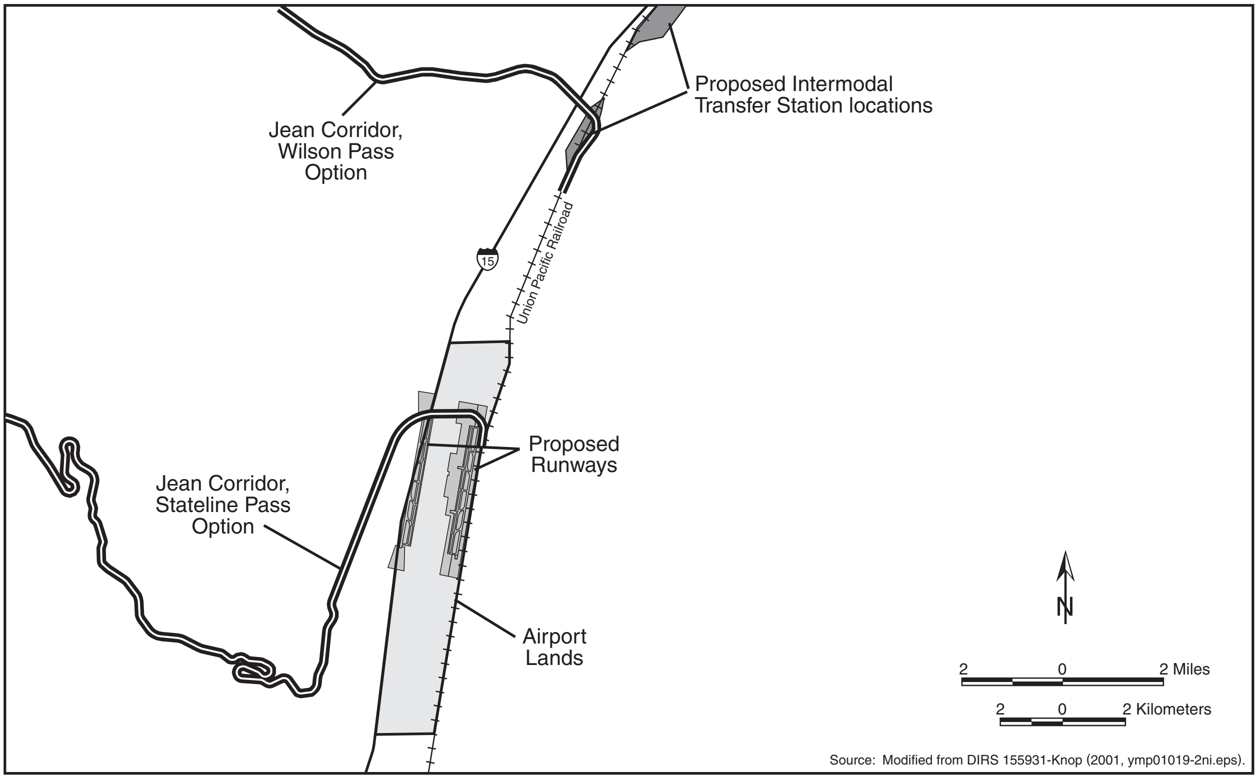

Figure J-17. Land-use conflicts along Nevada rail corridors, Ivanpah Valley Airport Public Lands Transfer Act.

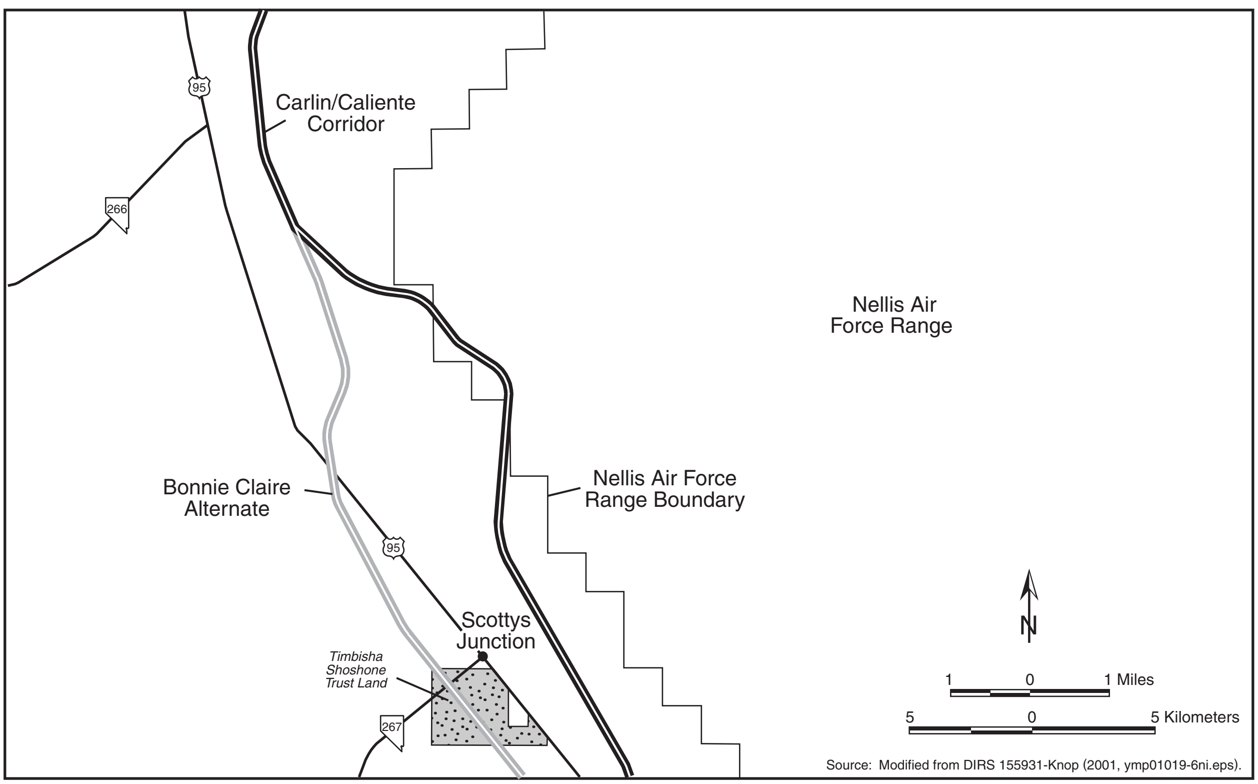

Figure J-18. Land-use conflicts along Nevada rail corridors, Nellis Air Force Range, Scottys Junction area.

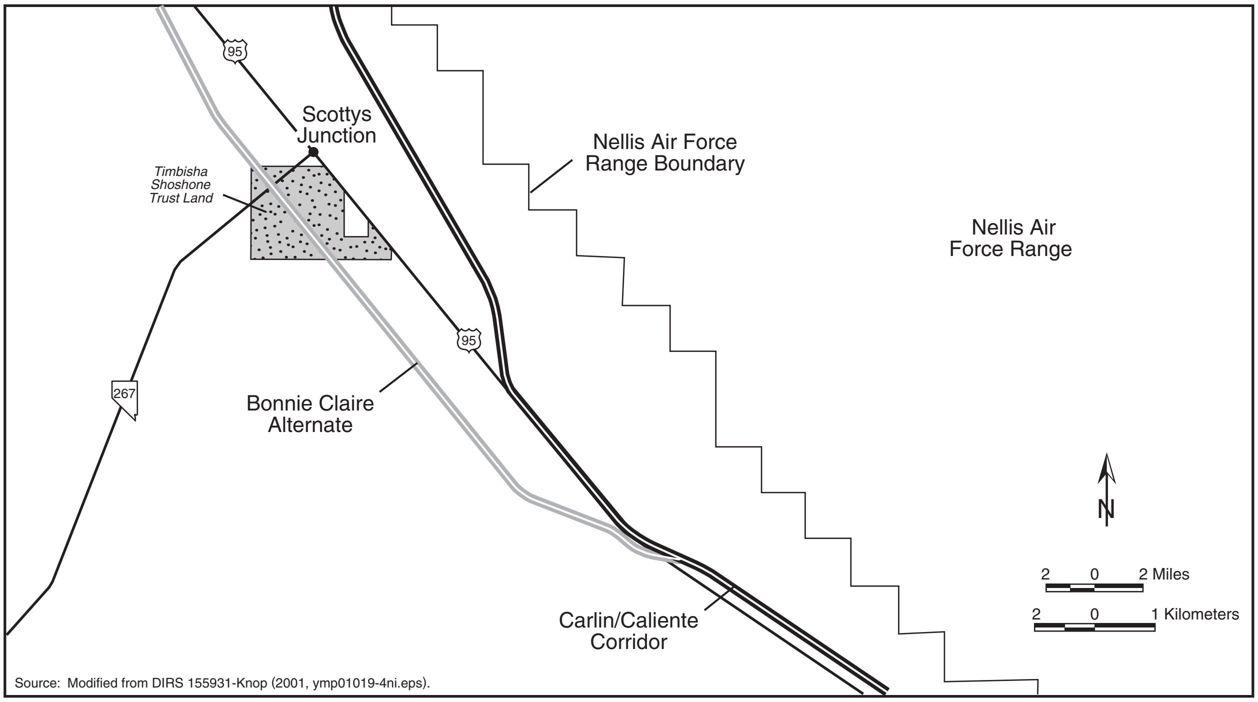

Figure J-19. Land-use conflicts along Nevada rail corridors, Timbisha Shoshone Trust Lands.

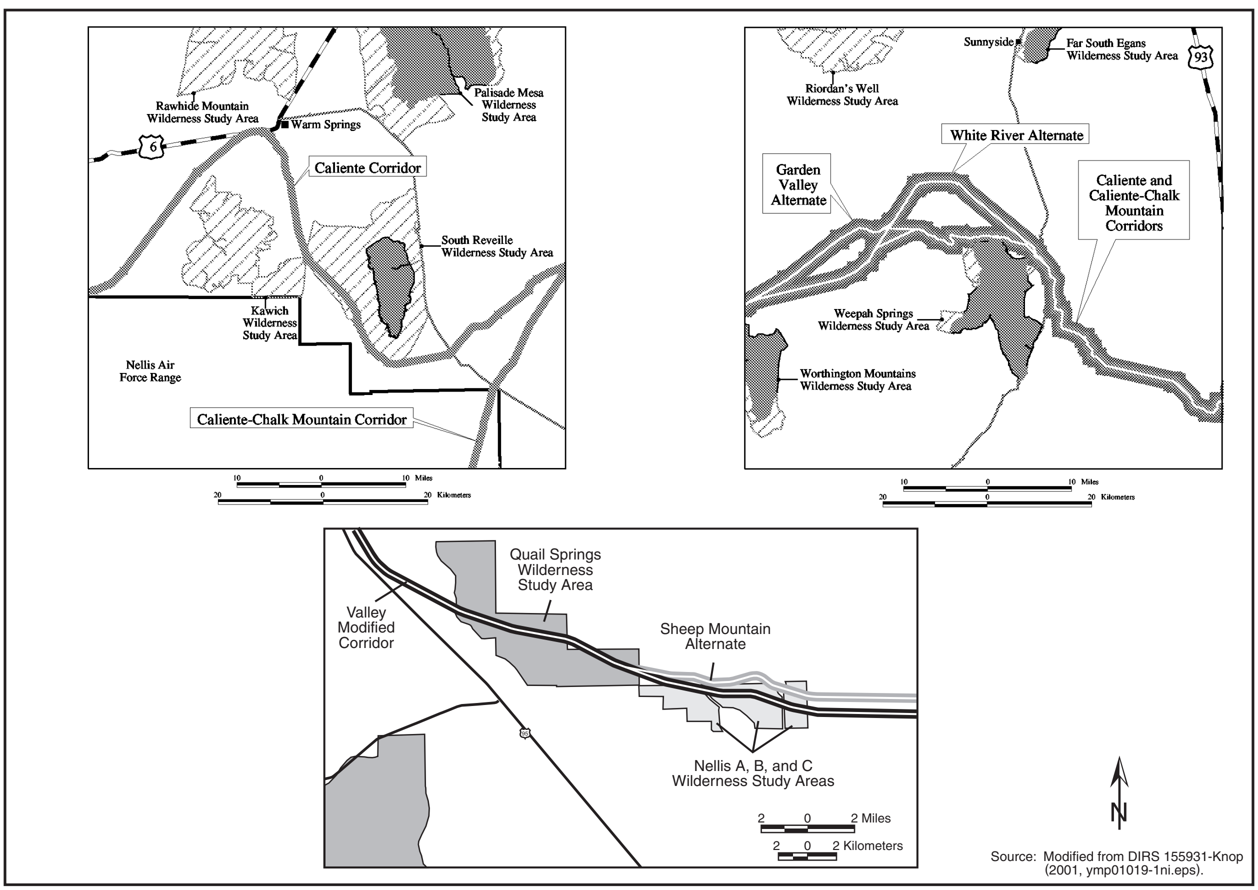

Figure J-20. Land-use conflicts along Nevada rail corridors, Wilderness Study Areas.

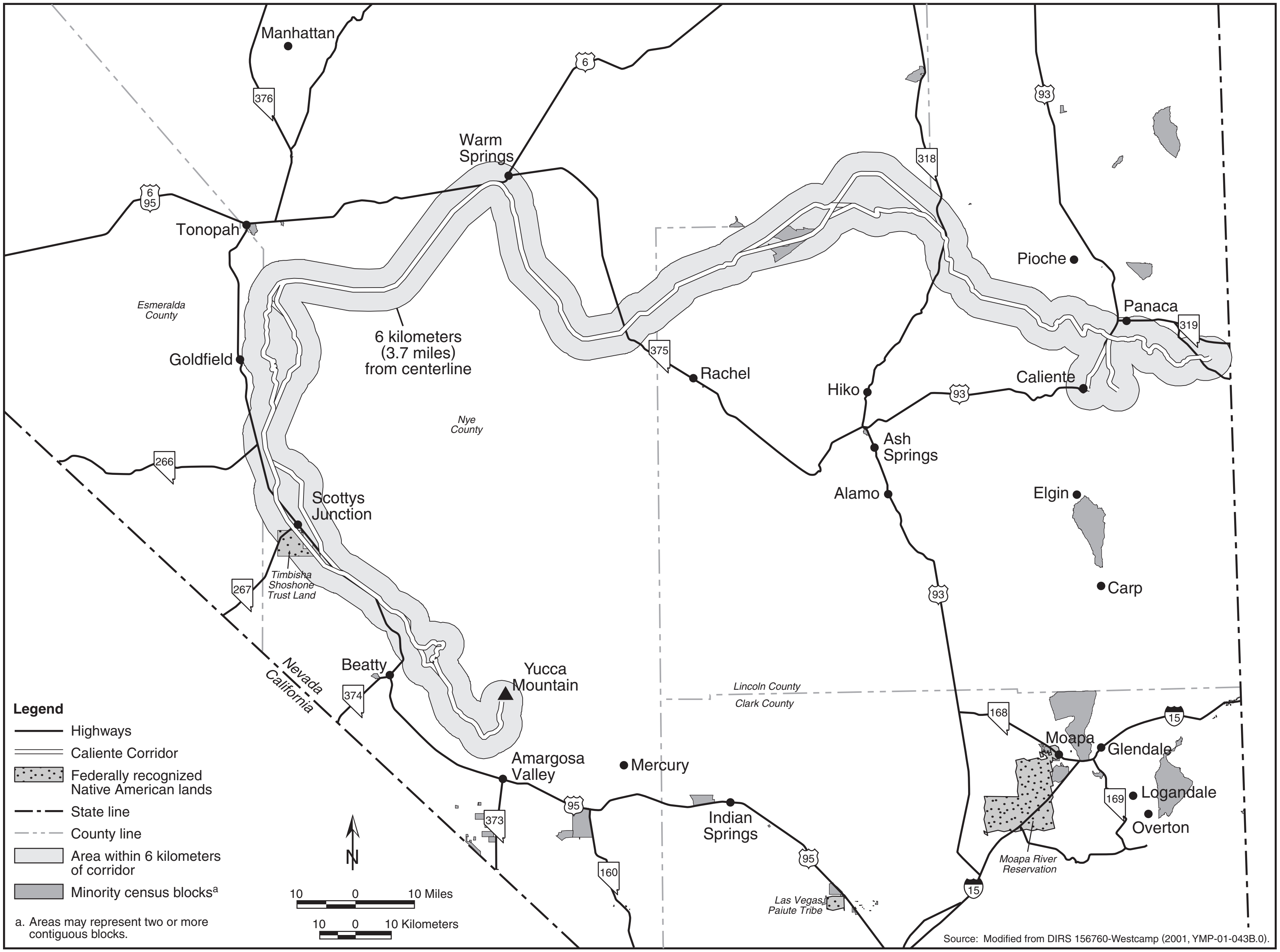

Figure J-21. Nevada minority census blocks in relation to the Caliente Corridor.

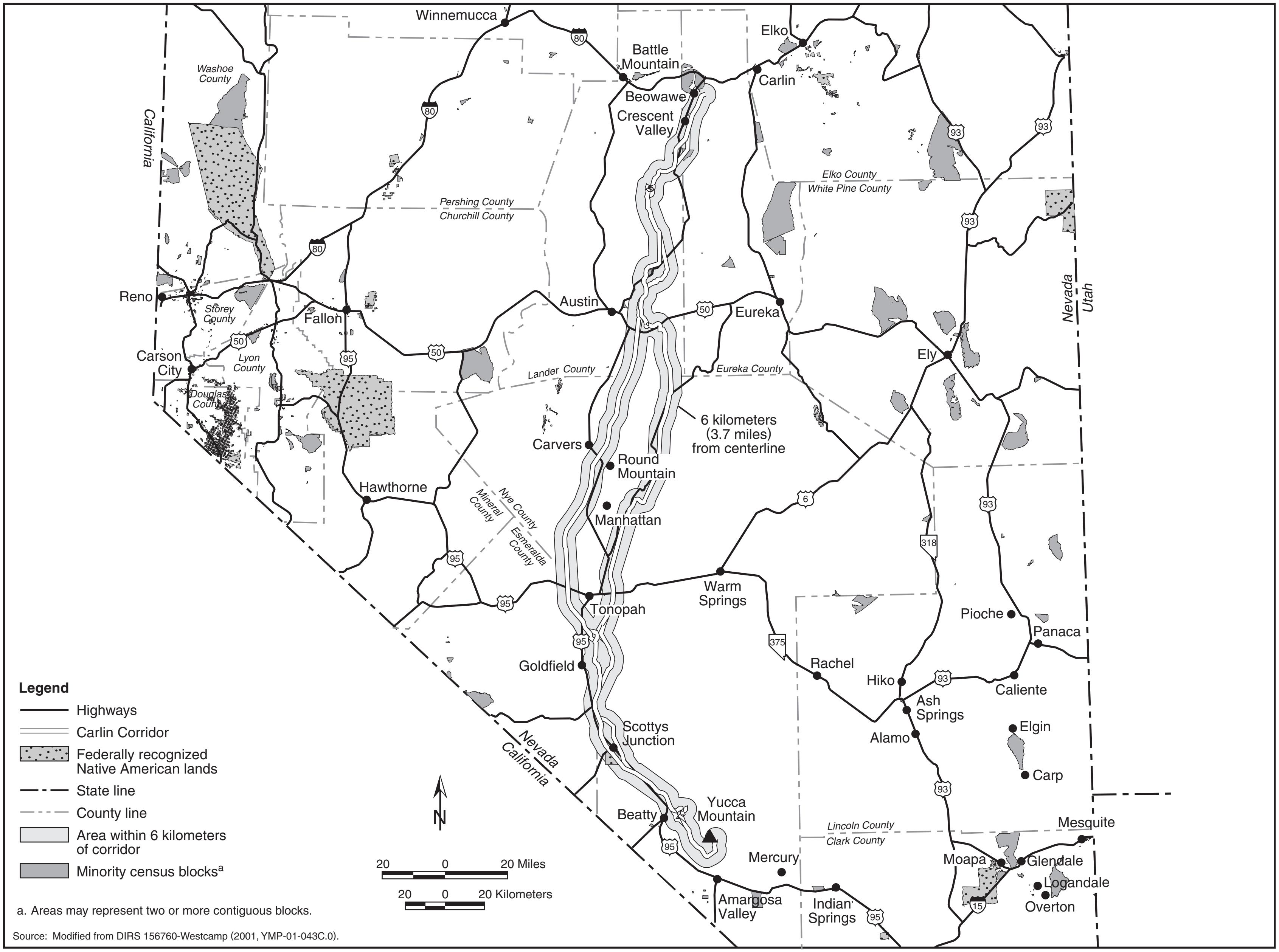

Figure J-22. Nevada minority census blocks in relation to the Carlin Corridor.

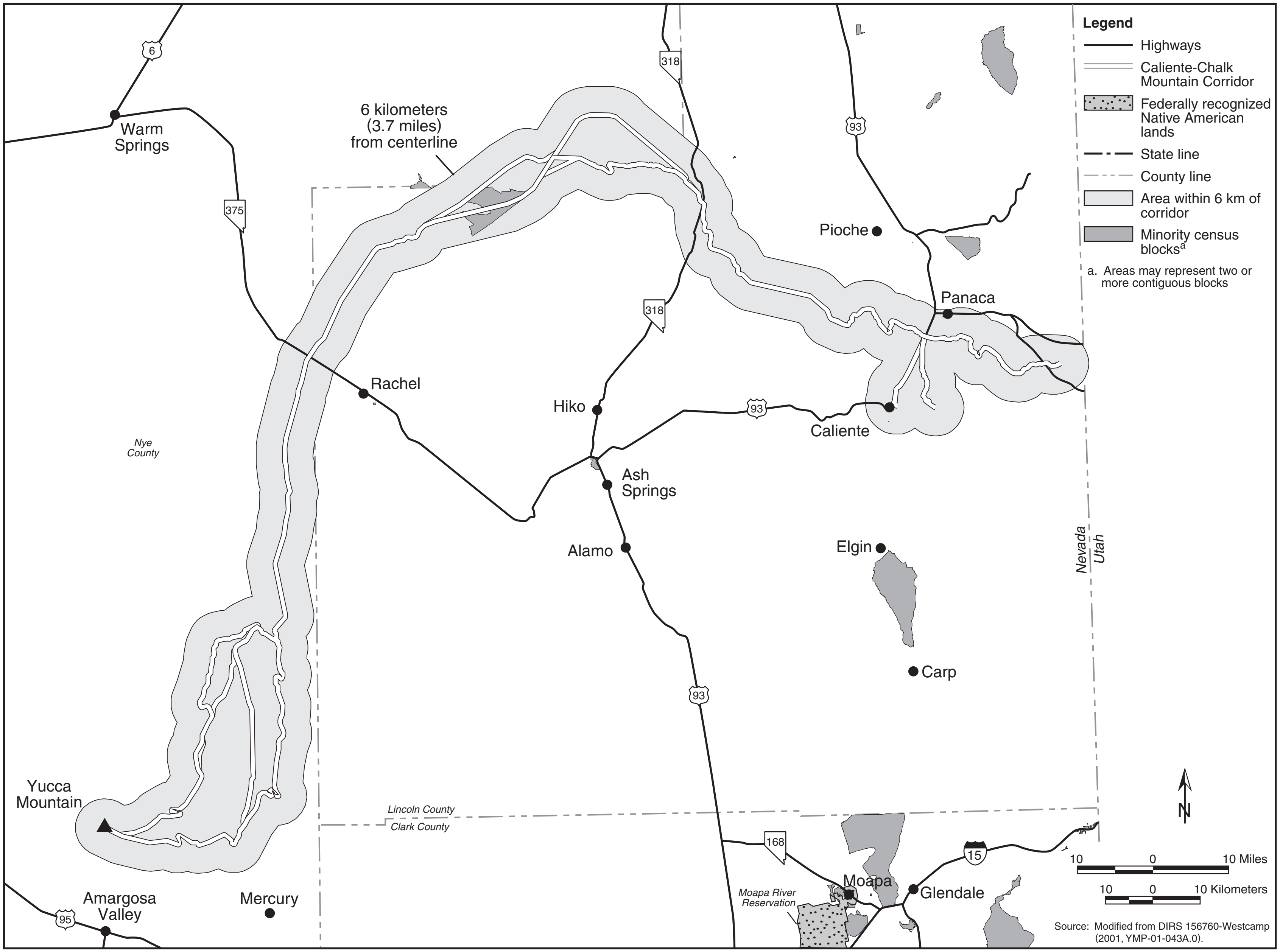

Figure J-23. Nevada minority census blocks in relation to the Caliente-Chalk Mountain Corridor.

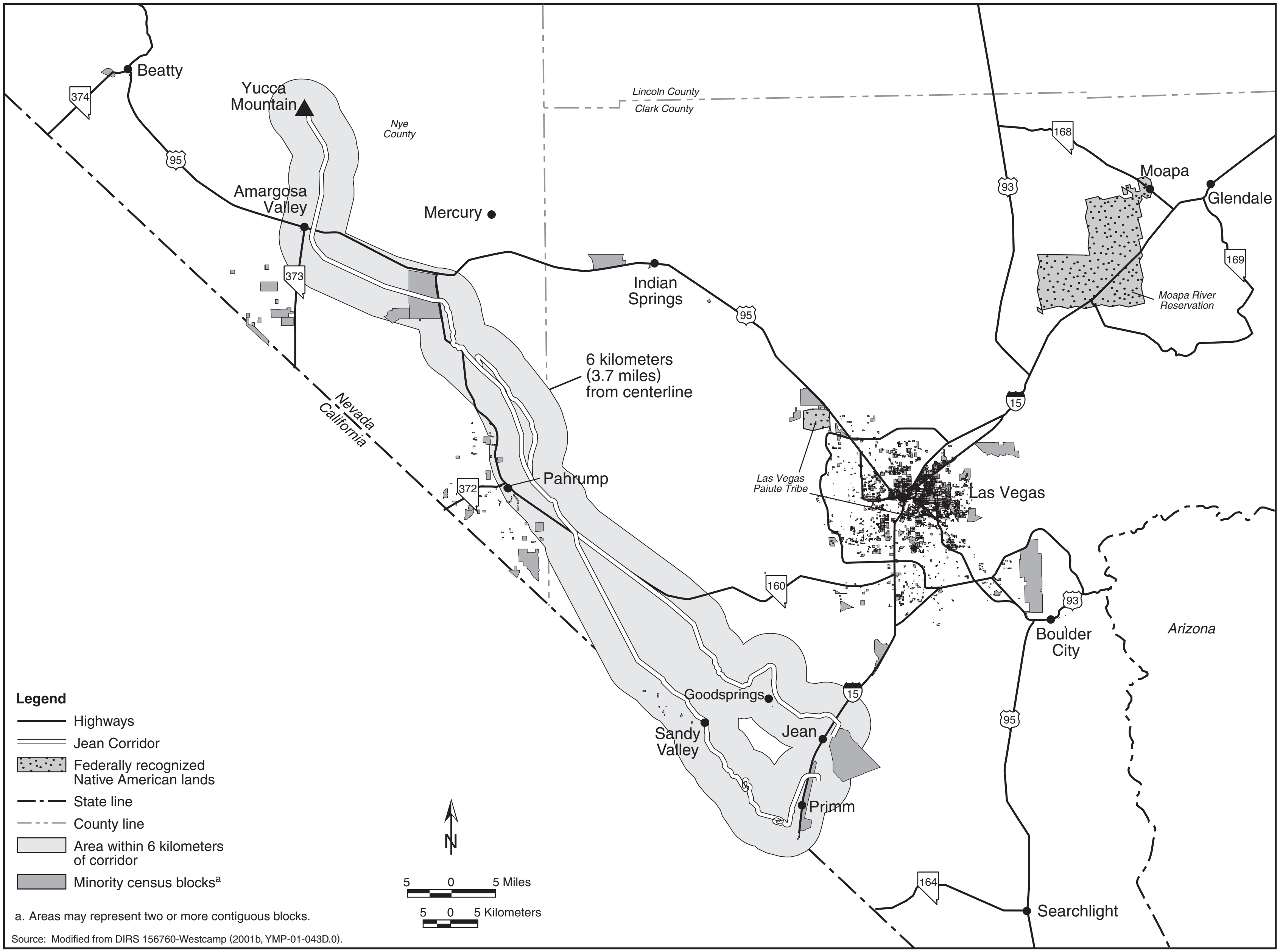

Figure J-24. Nevada minority census blocks in relation to the Jean Corridor.

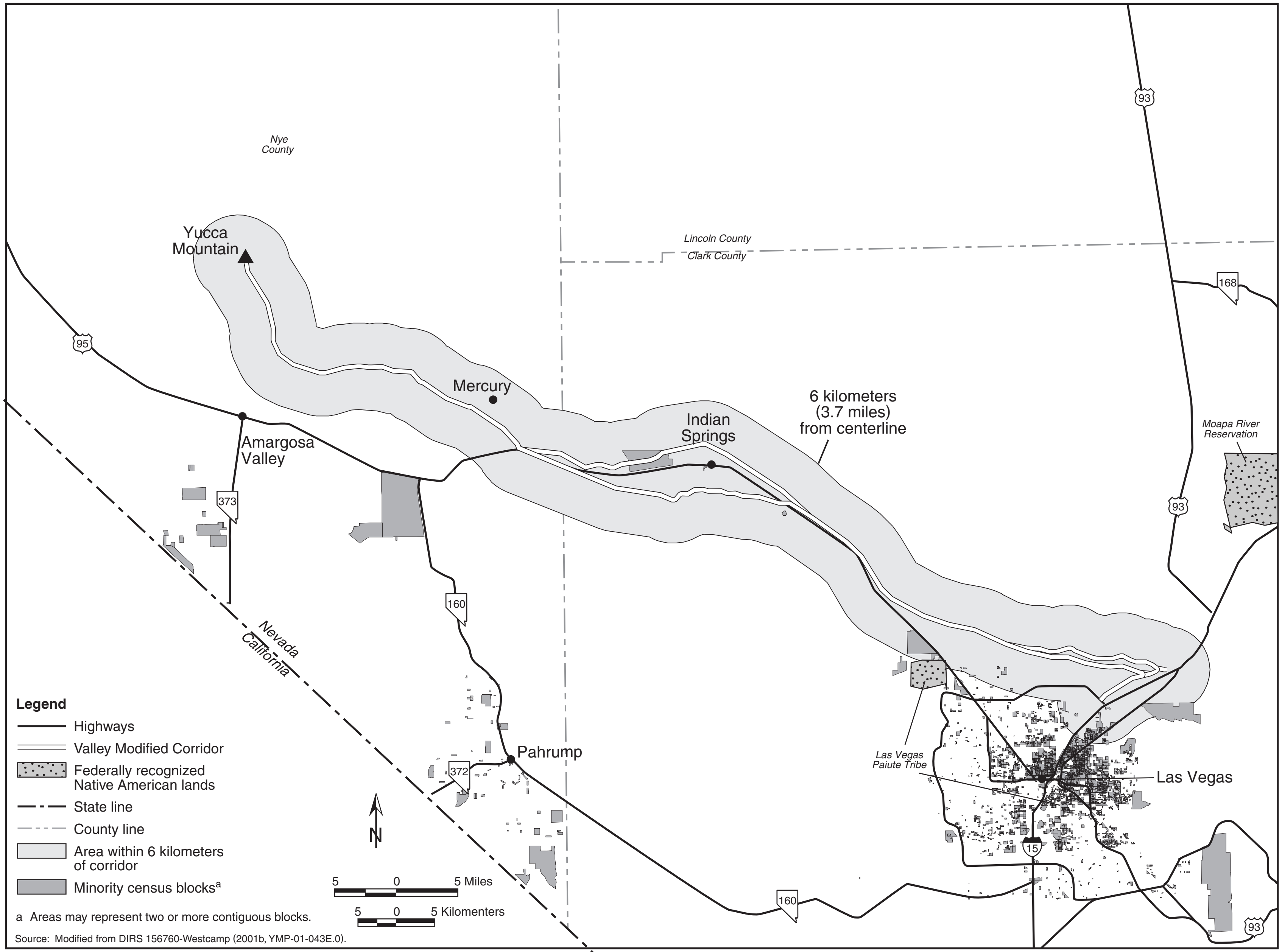

Figure J-25. Nevada minority census blocks in relation to the Valley Modified Corridor.

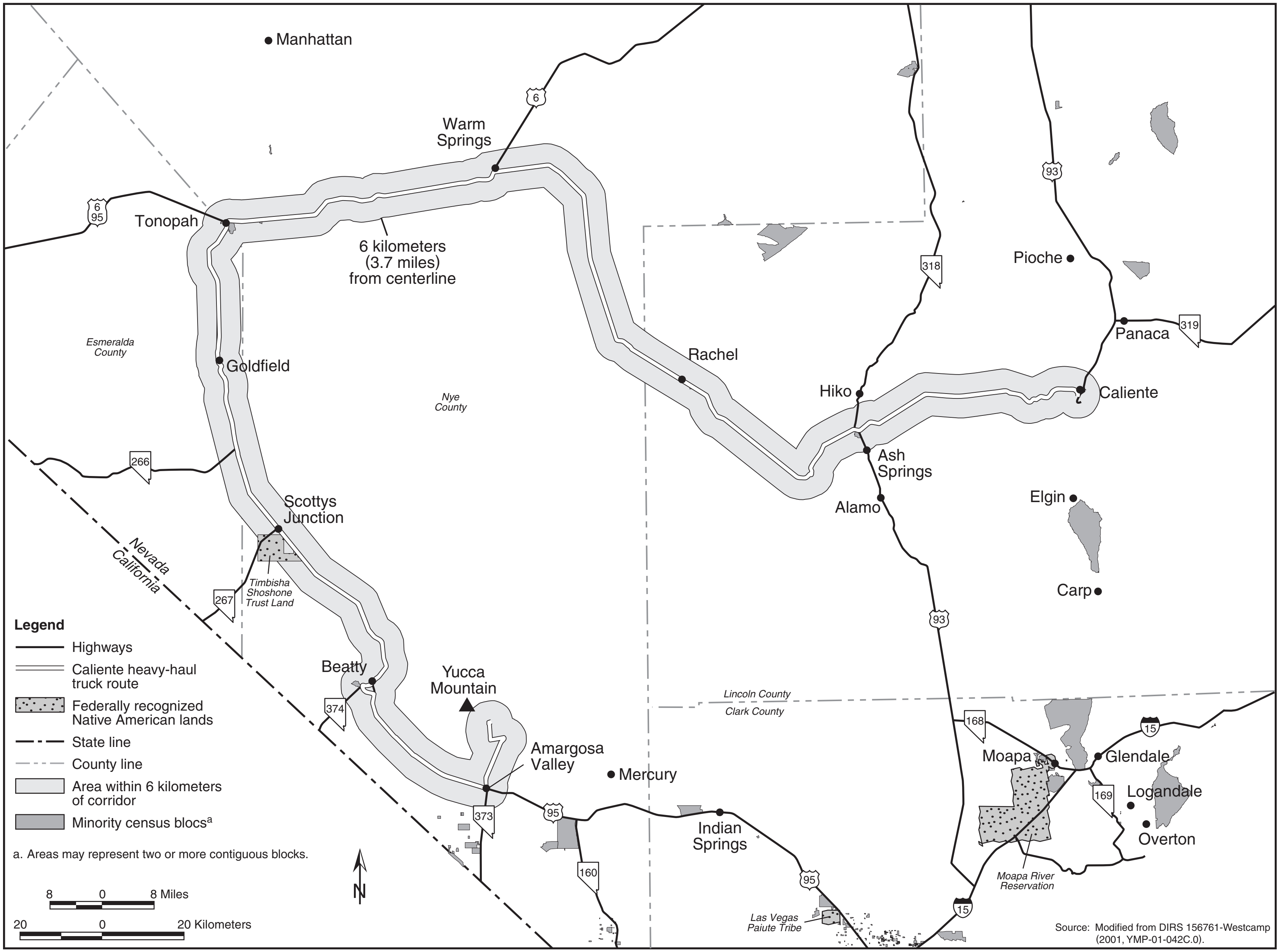

Figure J-26. Nevada minority census blocks in relation to the Caliente heavy-haul truck implementing alternative.

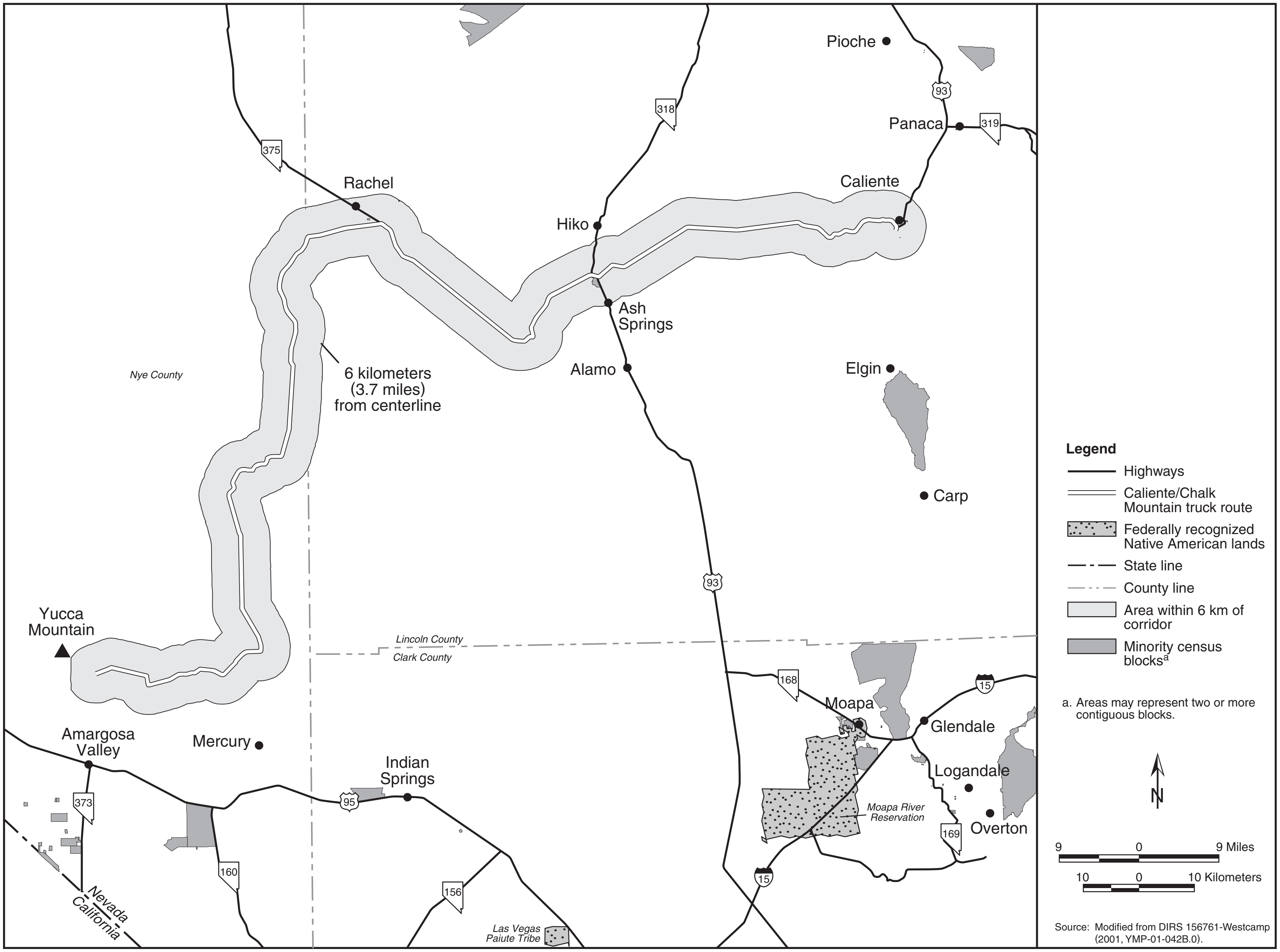

Figure J-27. Nevada minority census blocks in relation to the Caliente/Chalk Mountain route for heavy-haul trucks.

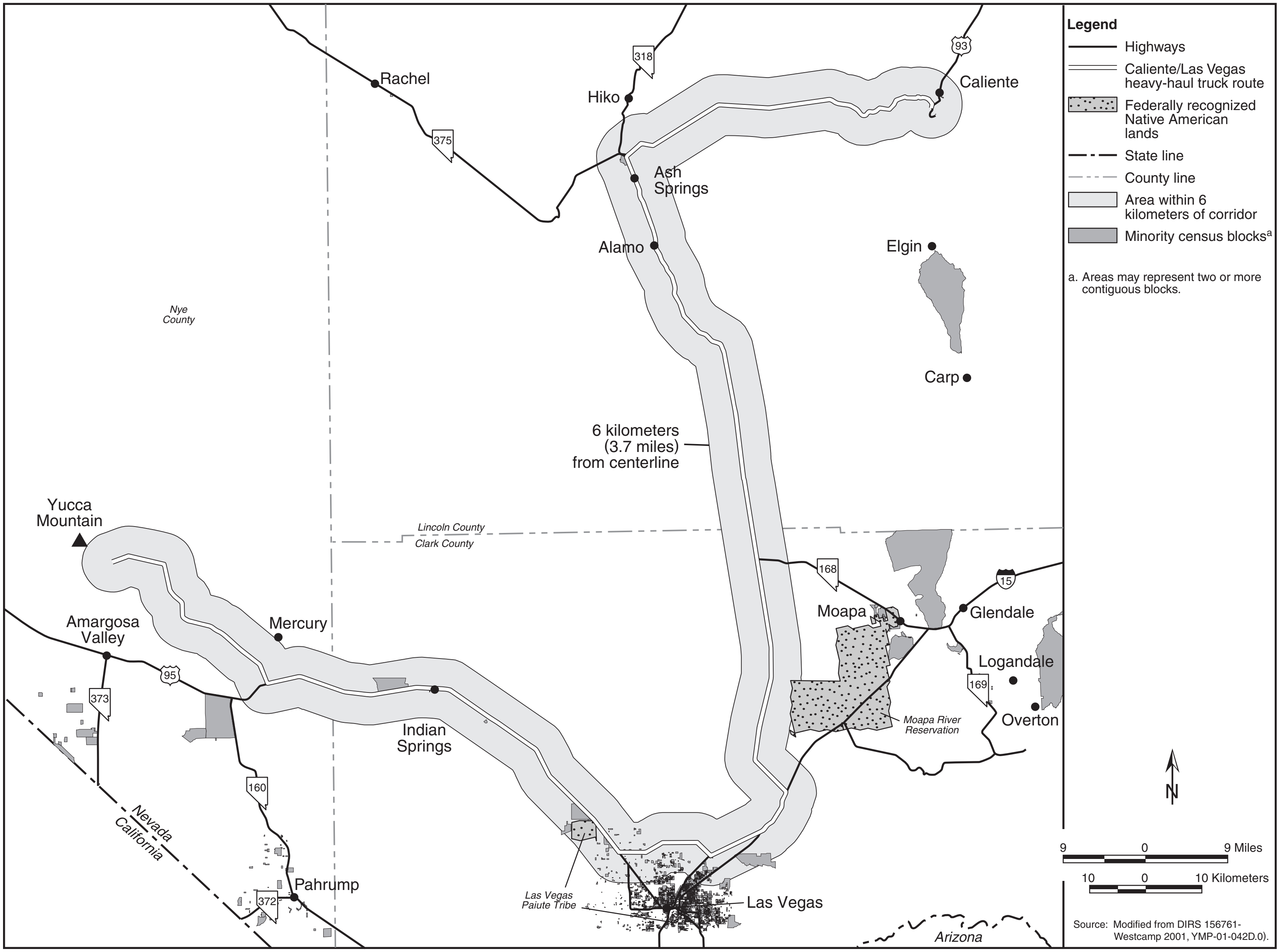

Figure J-28. Nevada minority census blocks in relation to the Caliente/Las Vegas route for heavy-haul trucks.

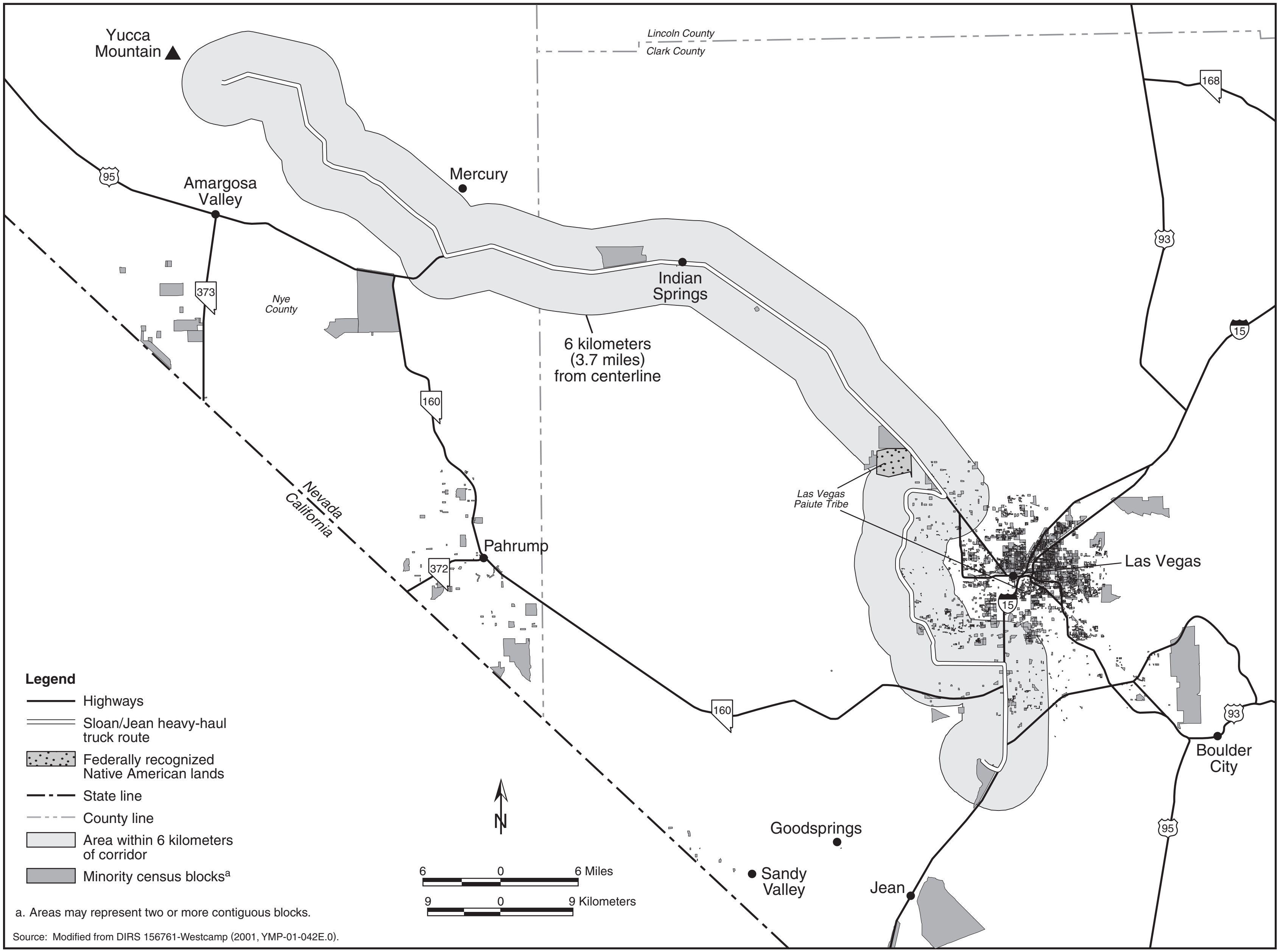

Figure J-29. Nevada minority census blocks in relation to the Sloan/Jean route for heavy-haul trucks.

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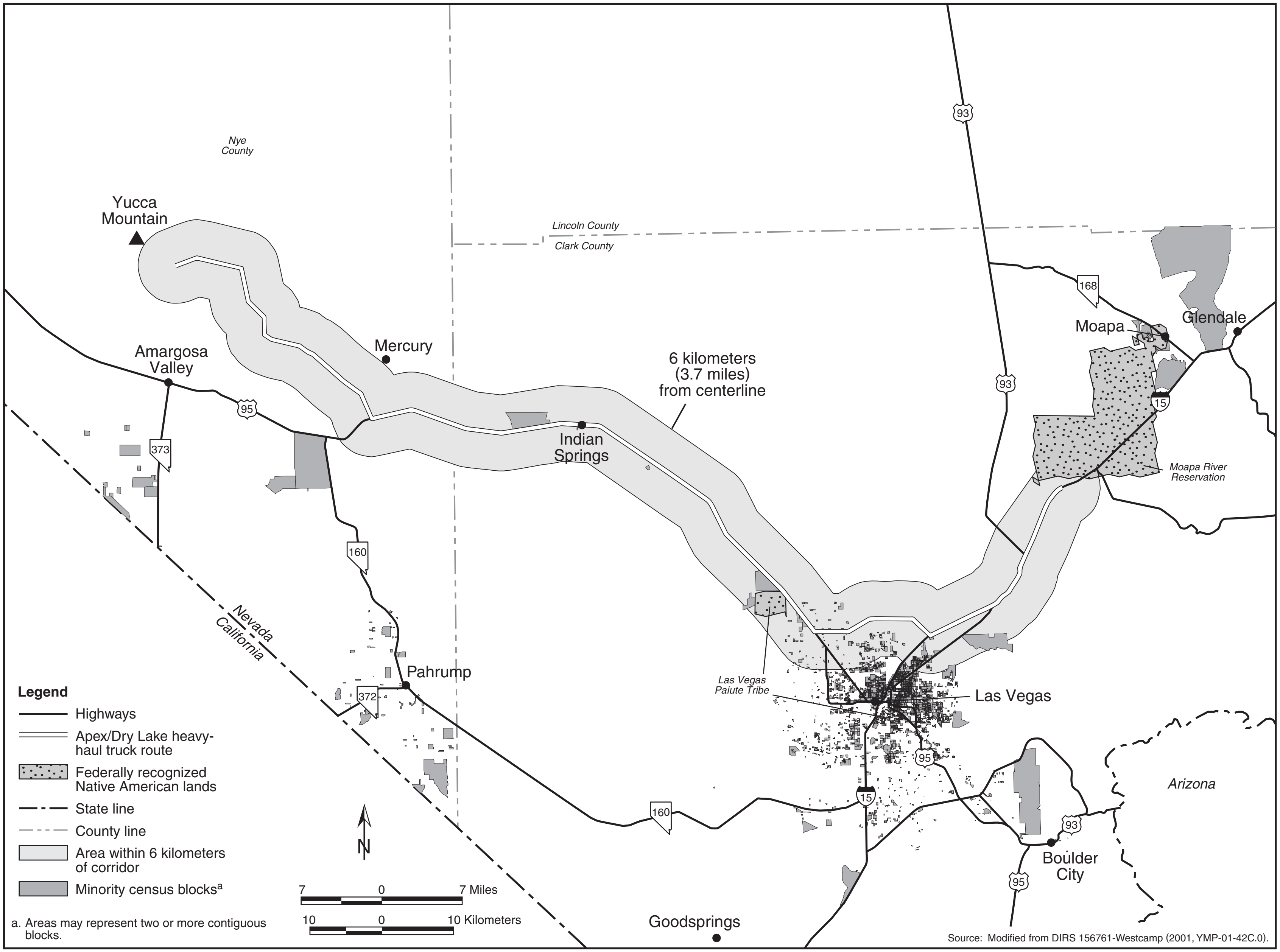

Figure J-30. Nevada minority census blocks in relation to the Apex/Dry Lake route for heavy-haul trucks.

Table J-46. Nevada routing sensitivity cases analyzed for a legal-weight truck.

Case	Description
Case 1	To Yucca Mountain via Barstow, California, using I-15 to Nevada 160 to Nevada 160 (Nevada D and F)
Case 2	To Yucca Mountain via Barstow using I-15 to California route 127 to Nevada 373 to US 95 (Nevada C)
Case 3	To Yucca Mountain via Needles using U.S. 95 to Nevada 164 to I-15 to California 127 to Nevada 373 and U.S. 95 (Nevada E)
Case 4	To Yucca Mountain via Needles using U.S. 95 to Nevada 164 to I-15 to Nevada 160 (variation of Nevada E)
Case 5	To Yucca Mountain via Wendover using U.S. 93 Alternate to U.S. 93 to U.S. 6 to U.S. 95 (Nevada B)
Case 6	To Yucca Mountain via Wendover using U.S. 93 Alternate to U.S. 93 to Nevada 318 to U.S. 93 to I-15 to the Las Vegas Beltway to U.S. 95 (Nevada A)
Case 7	To Yucca Mountain via Las Vegas using I-15 (for shipments entering Nevada at both the Arizona and California borders) to U.S. 95 (Spaghetti Bowl interchange)

J.3.2 ANALYSIS OF INCIDENT-FREE TRANSPORTATION IN NEVADA

The analysis of incident-free impacts to populations in Nevada addressed transportation through urban, suburban, and rural population zones. The population densities used in the analysis were determined using Geographic Information System methods, population data from the 1990 Census, and projected populations along the Las Vegas Beltway (DIRS 155112-Berger 2000, pp. 59 to 64). The analysis extrapolated impacts to account for population growth to 2035. The populations within the 800-meter (0.5-mile) regions of influence used to evaluate the impacts of incident-free transportation for legal-weight truck, heavy-haul truck, and rail shipments are listed in Table J-35. The table lists the estimated 2035 populations.

Average highway vehicle densities for Nevada were calculated from vehicle traffic counts on Interstate and primary U.S. highways in Nevada counties that would be used for transporting spent nuclear fuel and high-level radioactive waste (DIRS 156930-NDOT 2001, all). The analysis used the average speed of trains on a branch rail line in Nevada from (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Line Operations Plan). Heavy-haul trucks in Nevada would be escorted. The analysis assumed that heavy-haul truck shipments would originate in Caliente, Nevada, and would stop overnight en route to the repository. Input parameters for analysis of incident-free transportation in Nevada that differ from, or are additional to, values used to analyze impacts outside the State, are listed in Table J-49. Parameters not listed in this table are the same as those listed in Tables J-15 and J-17. Unit risk factors for incident-free transportation in Nevada are listed in Table J-50.

Results for incident-free transportation of spent nuclear fuel and high-level radioactive waste for Inventory Modules 1 and 2 are presented in Section J.3.4.

J.3.3 ANALYSIS OF TRANSPORTATION ACCIDENT SCENARIOS IN NEVADA

Section J.1.4 discusses the methodology for estimating the risks of accidents that could occur during rail and truck transportation of spent nuclear fuel and high-level radioactive waste. Section J.3.5 describes the results of the accident risk analysis for Inventory Modules 1 and 2.

J.3.3.1 Intermodal Transfer Station Accident Methodology

Shipping casks would arrive at an intermodal transfer station in Nevada by rail, and a gantry crane would transfer them from the railcars to heavy-haul trucks for transportation to the repository. The casks, which would not be opened or altered in any way at the intermodal transfer station, would be certified by the Nuclear Regulatory Commission and would be designed for accident conditions specified in 10 CFR Part 71. Impact limiters, which would protect casks against collisions during transportation, would remain in place during transfer operations at the intermodal transfer station.

Table J-47. Comparison of national impacts from the sensitivity analyses.

Impact	Base case	Case 1 Barstow via Nevada 160	Case 2 Barstow via California 127	Case 3 Needles via Nevada 160	Case 4 Needles via U.S. 95	Case 5 Wendover via U.S. 95	Case 6 Wendover via Las Vegas Beltway	Case 7 I-15 and U.S. 95 (Spaghetti Bowl)
Public incident-free dose (person-rem)	5,000	5,200	5,100	4,900	5,000	4,600	4,800	5,100
Occupational incident-free dose (person-rem)	14,000	15,000	15,000	14,000	14,000	15,000	15,000	14,000
Nonradioactive pollution health effects	0.93	0.93	0.93	0.89	0.88	0.79	0.81	1.1
Public incident-free risk of latent cancer fatality	2.5	2.6	2.6	2.4	2.5	2.3	2.4	2.6
Occupational incident-free risk of latent cancer fatality	5.6	6	5.8	5.6	5.7	5.9	5.9	5.6
Radiological accident risk (person-rem)	0.46	0.36	0.35	0.35	0.35	0.39	0.4	0.52
Radiological accident risk of latent cancer fatality	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003
Traffic fatalities	4.5	4.5	4.2	4.3	4.2	4.9	5	4.5

Table J-48. Comparison of Nevada impacts from the sensitivity analyses.

Impact	Base case	Case 1 Barstow via Nevada 160	Case 2 Barstow via California 127	Case 3 Needles via Nevada 160	Case 4 Needles via U.S. 95	Case 5 Wendover via U.S. 95	Case 6 Wendover via Las Vegas Beltway	Case 7 I-15 and U.S. 95 (Spaghetti Bowl)
Public incident-free dose (person-rem)	340	180	35	170	83	360	490	480
Occupational incident-free dose (person-rem)	1,900	1,800	1,200	1,800	1,400	3,400	3,500	1,900
Nonradioactive pollution health effects	0.09	0.01	<0.005	0.01	<0.005	0.03	0.04	0.21
Public incident-free risk of latent cancer fatality	0.17	0.09	0.02	0.08	0.04	0.18	0.24	0.24
Occupational incident-free risk of latent cancer fatality	0.75	0.72	0.47	0.7	0.54	1.4	1.4	0.74
Radiological accident risk (person-rem)	0.052	0.005	0.002	0.004	0.002	0.015	0.027	0.11
Radiological accident risk of latent cancer fatality	0.000026	0.000003	0.000001	0.000002	0.000001	0.000008	0.000013	0.000055
Traffic fatalities	0.5	0.4	0.1	0.4	0.2	1.3	1.3	0.5

Table J-49. Input parameters and parameter values used for incident-free Nevada truck and rail transportation different from national parameters.

Parameter	Legal-weight truck	Rail	Heavy-haul truck
Speed (kilometers per hour)[a]			
Rural		50	
One-way traffic count (vehicles per hour)			
Rural	(b)		
Suburban	(b)		
Urban	(b)		
Truck crew dose at walkaround inspections			
Distance of crew from cargo (meters)[c]			30
Truck escort dose at walkaround inspections			
Distance of one inspector (meters)			1
Distance of 3 other escorts (meters)			60
Guards at overnight stop[d]			
Distance of 4 guards from cargo (meters)			60
Time of overnight stop (hours)			12

a. To convert kilometers to miles, multiply by 0.62137.
b. County-specific average traffic counts (DIRS 156930-NDOT 2001, all)
c. To convert meters to feet, multiply by 3.2808.
d. Crew and escorts are far enough away from the cargo and shielded sufficiently that they receive no dose from the cargo during the overnight stop. Number of guards and length of overnight stop are assumptions for analysis purposes.

Table J-50. Per-shipment unit risk factors for incident-free transportation of spent nuclear fuel and high-level radioactive waste in Nevada.

Factor	Heavy-haul truck	Rail	Legal-weight truck
Public			
Off-link [rem per (persons per square kilometers) per kilometer]			
Rural	6.24×10^{-8}	5.01×10^{-8}	2.89×10^{-8}
Suburban	6.24×10^{-8}	6.24×10^{-8}	3.18×10^{-8}
Urban	6.24×10^{-8}	1.04×10^{-7}	3.18×10^{-8}
On-link (person-rem per kilometer)[a]			
Rural	1.46×10^{-4}	2.00×10^{-7}	1.38×10^{-5}
Suburban	1.12×10^{-4}	1.55×10^{-6}	3.89×10^{-5}
Urban	5.40×10^{-4}	4.29×10^{-6}	1.87×10^{-4}
Residents near rest/refueling stops (rem per (persons per square kilometer) per kilometer)			
Rural	3.96×10^{-9}	1.24×10^{-7}	5.50×10^{-9}
Suburban	3.96×10^{-9}	1.24×10^{-7}	5.50×10^{-9}
Urban	3.96×10^{-9}	1.24×10^{-7}	5.50×10^{-9}
Residents near classification stops [rem per (persons per square kilometer)]			
Suburban	1.59×10^{-5}		
Public near rest/refueling stops (person-rem per kilometer)			7.86×10^{-6}
Workers			
Classification stop (person-rem)		8.07×10^{-3}	
In-transit stop (person-rem per kilometer)		1.45×10^{-5}	
In moving vehicle (person-rem per kilometer)			
Rural	5.54×10^{-6}		4.52×10^{-5}
Suburban	5.54×10^{-6}		4.76×10^{-5}
Urban	5.54×10^{-6}		4.76×10^{-5}
Crew, walkaround inspection (person-rem per kilometer)	6.27×10^{-7}		1.93×10^{-5}
Escort, walkaround inspection (person-rem per kilometer)	1.50×10^{-5}		
Guards at overnight stops (person-rem)	2.62×10^{-3}		

a. Listed values for on-link unit risk factors are based on Clark County traffic counts. The analysis used country-specific counts for each country through which shipments would pass.

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DOE performed an accident screening process to identify credible accidents that could occur at an intermodal transfer station with the potential for compromising the integrity of the casks and releasing radioactive material. The external events listed in Table J-51 were considered, along with an evaluation of their potential applicability.

As indicated from Table J-51, the only accident-initiating event identified from among the feasible external events was the aircraft crash. Such events would be credible only for casks being handled or on transport vehicles at an intermodal transfer station in the Las Vegas area (Apex/Dry Lake or Sloan/Jean).

For a station in the Las Vegas area, an aircraft crash would be from either commercial aircraft operations at McCarran airport or military operations from Nellis Air Force Base.

Among the internal events, the only potential accident identified was a drop of the cask during transfer operations. This accident would bound the other events considered, including drops from the railcar or truck (less fall height would be involved than during the transfer operations). Collisions, derailments, and other accidents involving the transport vehicles at the intermodal transfer station would not damage the casks due to the requirement that they be able to withstand high-speed impacts and the low velocities of the transport vehicles at the intermodal transfer station.

Accident Analysis

1. *Cask Drop Accident.* The only internal event retained after the screening process was a failure of the gantry crane (due to mechanical failure or human error) during the transfer of a shipping cask from a railcar to a heavy-haul truck. The maximum height between the shipping cask and the ground during the transfer operation would be less than 6 meters (19 feet) (DIRS 104849-CRWMS M&O 1997, all). The casks would be designed to withstand a 9-meter (30-foot) drop. Therefore, the cask would be unlikely to fail during the event, especially because the impact energy from the 6-meter drop would be only 65 percent of the minimum design requirement.

2. *Aircraft Crash Accident.* This section, including Tables J-52 and J-53, has been moved to Volume IV of this EIS.

J.3.4 IMPACTS IN NEVADA FROM INCIDENT-FREE TRANSPORTATION FOR INVENTORY MODULES 1 AND 2

This section presents the analysis of impacts to occupational and public health and safety in Nevada from incident-free transportation of spent nuclear fuel and high-level radioactive waste in Inventory Modules 1 and 2. The analysis assumed that the routes, population densities, and shipment characteristics (for example, radiation from shipping casks) for shipments under the Proposed Action and Inventory Modules 1 and 2 would be the same. The only difference was the projected number of shipments that would travel to the repository.

The following sections provide detailed information on the range of potential impacts to occupational and public safety and health from incident-free transportation of Modules 1 and 2 that result from legal-weight trucks and the 10 alternative transportation routes considered in Nevada. National impacts of incident-free transportation of Modules 1 and 2 incorporating Nevada impacts are discussed together with other cumulative impacts in Chapter 8.

J.3.4.1 Mostly Legal-Weight Truck Scenario

Tables J-54 and J-55 list estimated incident-free impacts in Nevada for the mostly legal-weight truck scenario for shipments of materials included in Inventory Modules 1 and 2.

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Table J-51. Screening analysis of external events considered potential accident initiators at intermodal transfer station.

Event	Applicability
Aircraft crash	Retained for further evaluation
Avalanche	(a)
Coastal erosion	(a)
Dam failure	See flooding
Debris avalanching	(a)
Dissolution	(b)
Epeirogenic displacement (tilting of the earth's crust)	(c)
Erosion	(b)
Extreme wind	(c)
Extreme weather	(e)
Fire (range)	(b)
Flooding	(d)
Denudation (loss of land cover)	(b)
Fungus, bacteria, algae	(b)
Glacial erosion	(b)
High lake level	(b)
High tide	(a)
High river stage	See flooding
Hurricane	(a)
Inadvertent future intrusion	(b)
Industrial activity	Bounded by aircraft crash
Intentional future intrusion	(b)
Lightning	(c)
Loss of off/on site power	(c)
Low lake level	(b)
Meteorite impact	(e)
Military activity	Retained for further evaluation
Orogenic diastrophism (tectonic ground movement)	(e)
Pipeline accident	(b)
Rainstorm	See flooding
Sandstorm	(c)
Sedimentation	(b)
Seiche (sudden water-level change)	(a)
Seismic activity, uplifting	(c)
Seismic activity, earthquake	(c)
Seismic activity, surface fault	(c)
Seismic activity, subsurface fault	(c)
Static fracturing	(b)
Stream erosion	(b)
Subsidence	(c)
Tornado	(c)
Tsunami (tidal wave)	(a)
Undetected past intrusions	(b)
Undetected geologic features	(b)
Undetected geologic processes	(c)
Volcanic eruption	(e)
Volcanism, magmatic activity	(e)
Volcanism, ash flow	(c)
Volcanism, ash fall	(b)
Waves (aquatic)	(a)

a. Conditions at proposed sites do not allow event.
b. Not a potential accident initiator.
c. Bounded by cask drop accident considered in the internal events analysis.
d. Shipping cask designed for event.
e. Not credible, see evaluation for repository.

Table J-54. Population doses and radiological impacts from incident-free Nevada transportation for mostly legal-weight truck scenario–Modules 1 and 2.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Total[c]
Module 1			
Involved worker			
Collective dose (person-rem)	3,700	21	3,700
Estimated latent cancer fatalities	1.5	0.008	1.5
Public			
Collective dose (person-rem)	680	10	690
Estimated latent cancer fatalities	0.34	0.005	0.35
Module 2			
Involved worker			
Collective dose (person-rem)	3,800	23	3,900
Estimated latent cancer fatalities	1.5	0.009	1.5
Public			
Collective dose (person-rem)	700	13	710
Estimated latent cancer fatalities	0.35	0.007	0.36

a. Impacts are totals for shipments over 38 years.
b. Includes impacts at intermodal transfer stations.
c. Totals might differ from sums due to rounding.

Table J-55. Population health impacts from vehicle emissions during incident-free Nevada transportation for the mostly legal-weight truck scenario–Modules 1 and 2.[a]

Vehicle emission-related fatalities	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Total[c]
Module 1	0.17	0.0069	0.18
Module 2	0.18	0.0081	0.19

a. Impacts are totals for shipments over 38 years.
b. Includes heavy-haul truck shipments in Nevada.
c. Totals might differ from sums due to rounding.

J.3.4.2 Nevada Rail Implementing Alternatives

Table J-56 lists the range of estimated incident-free impacts in Nevada for the operation of a branch rail line to ship the materials included in Inventory Modules 1 and 2. It lists impacts that would result from operations for a branch line in each of the five possible rail corridors DOE is evaluating. These include the impacts of about 3,100 legal-weight truck shipments from commercial sites that could not use rail casks to ship spent nuclear fuel.

J.3.4.3 Nevada Heavy-Haul Truck Implementing Alternatives

Radiological Impacts

Intermodal Transfer Station Impacts. Involved worker exposures (the analysis assumed that the noninvolved workers would receive no radiation exposure and thus required no further analysis) would occur during both inbound (to the repository) and outbound (to the 77 sites) portions of the shipment campaign. DOE used the same involved worker level of effort it used in the analysis of intermodal transfer station worker industrial safety impacts to estimate collective involved worker radiological impacts (that is, 16 full-time equivalents per year). The collective worker radiation doses were adapted from a study (DIRS 104791-DOE 1992, all) of a spent nuclear fuel transportation system, which was also performed for the commercial sites. That study found that the collective worker doses that could be incurred during similar inbound and outbound transfer operations of a single loaded (with commercial

Table J-56. Radiological and nonradiological impacts from incident-free Nevada transportation for the rail implementing alternatives–Modules 1 and 2.[a]

Category	Legal-weight truck shipments	Rail shipments	Total[b]
Involved worker			
Collective dose (person-rem)	110	1,300 - 1,900	1,400 - 2,000
Estimated latent cancer fatalities	0.04	0.52 - 0.76	0.56 - 0.8
Public			
Collective dose (person-rem)	19	106 - 640	130 - 659
Estimated latent cancer fatalities	0.01	0.05 - 0.32	0.07 - 0.33
Estimated vehicle emission-related fatalities	0.0046	0.012 - 0.38	0.016 - 0.38

a. Impacts are totals for shipments over 38 years.
b. Totals might differ from sums due to rounding.

spent nuclear fuel) and unloaded cask were approximately 0.027 and 0.00088 person-rem per cask, respectively, as listed in Table J-57.

Table J-57. Collective worker doses (person-rem) from transportation of a single cask.[a,b]

Inbound	Inbound CD[b]	Outbound	Outbound CD
Receive transport vehicle and loaded cask. Monitor, inspect, unhook offsite drive unit, and attach onsite drive unit.	6.3×10^{-3}	Receive transport vehicle and empty cask. Monitor, inspect, unhook offsite drive unit, and attach onsite drive unit.	0.0
Move cask to parking area and wait for wash down station. Attach to carrier puller when ready.	1.4×10^{-3}	Move cask to parking area and wait for wash down station. Attach to carrier puller when ready.	5.4×10^{-4}
Move cask to receiving and handling area.	9.2×10^{-5}	Move cask to receiving and handling area.	8.0×10^{-6}
Remove cask from carrier and place on cask cart.	4.3×10^{-3}	Remove cask from carrier and place on cask cart.	2.2×10^{-4}
Connect onsite drive unit and move cask to inspection area; disconnect onsite drive unit.	7.0×10^{-4}	Connect onsite drive unit and move cask to inspection area; disconnect onsite drive unit.	3.3×10^{-5}
Hook up offsite drive unit, move to gatehouse, perform final monitoring and inspection of cask.	1.4×10^{-2}	Hook up offsite drive unit, move to gatehouse, perform final monitoring and inspection of cask.	8.3×10^{-5}
Notify appropriate organizations of the shipment's departure.	0.0	Notify appropriate organizations of the shipment's departure.	0.0
Total	2.7×10^{-2}	*Total*	8.8×10^{-4}

a. Adapted from DIRS 104791-DOE (1992, Table 4.2).
b. Values are rounded to two significant figures; therefore, totals might differ from sums of values.
c. CD = collective dose (person-rem per cask).

The analysis used these inbound and outbound collective dose factors to calculate the involved worker impacts listed in Table J-58 for Module 1 and Module 2 inventories in the same manner it used for commercial power reactor spent nuclear fuel impacts. The number of inbound and outbound shipments for Module 1 and Module 2 inventories is from Section J.1.2. The worker impacts reflect two-way operations.

Incident-Free Transportation. Table J-59 lists the range of estimated incident-free impacts in Nevada for the use of heavy-haul trucks to ship the materials included in Inventory Modules 1 and 2. It lists impacts that would result from operations on each of the five possible highway routes in Nevada DOE is evaluating. These include impacts of about 3,100 legal-weight truck shipments from commercial sites under Modules 1 and 2 that could not ship spent nuclear fuel using rail casks while operational.

Table J-58. Doses and radiological health impacts to involved workers from intermodal transfer station operations – Modules 1 and 2.[a,b]

Group	Module 1		Module 2	
	Dose (millirem)	Latent cancer fatality	Dose (millirem)	Latent cancer fatality
Maximally exposed individual worker	12	0.005[c]	12	0.005
Involved worker population	500	0.20[d]	520	0.21

a. Includes estimated impacts from handling 300 shipments of Naval spent nuclear fuel that would be shipped by rail under the mostly legal-weight truck transportation scenario.
b. Totals for 38 years of operations.
c. The estimated probability of a latent cancer fatality in an exposed individual.
d. The estimated number of latent cancer fatalities in an exposed involved worker population.

Table J-59. Radiological and nonradiological health impacts from incident-free transportation for the heavy-haul truck implementing alternatives – Modules 1 and 2.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Total[c]
Involved worker			
Collective dose (person-rem)	110	2,100 - 3,100	2,200 - 3,300
Estimated latent cancer fatalities	0.04	0.85 - 1.3	0.89 - 1.3
Public			
Collective dose (person-rem)	19	100 - 580	120 - 600
Estimated latent cancer fatalities	0.01	0.05 - 0.29	0.06 - 0.3
Estimated vehicle emission-related fatalities	0.0046	0.0096 - 0.35	0.014 - 0.35

a. Impacts are totals for 38 years.
b. Includes impacts to workers at an intermodal transfer station.
c. Totals might differ from sums due to rounding.

J.3.5 IMPACTS IN NEVADA FROM TRANSPORTATION ACCIDENTS FOR INVENTORY MODULES 1 AND 2

The analysis assumed that the routes, population densities, and shipment characteristics (for example, assumed radioactive material contents of shipping casks) for the Proposed Action and Inventory Modules 1 and 2 would be the same. The only difference would be the projected number of shipments that would travel to the repository. As listed in Table J-1, Module 2 would include about 3 percent more shipments than Module 1.

J.3.5.1 Mostly Legal-Weight Truck Scenario

Radiological Impacts

The analysis estimated the radiological impacts of accidents in Nevada for the mostly legal-weight truck scenario for shipments of the materials included in Inventory Modules 1 and 2. The radiological health impacts associated with both Modules 1 and 2 would be 0.1 person-rem (see Table J-60). These impacts would occur over 38 years in a population of more than 1 million people who lived within 80 kilometers (50 miles) of the Nevada routes that DOE would use. This dose risk would lead to less than 1 chance in 1,000 of an additional cancer fatality in the exposed population. For comparison, in Nevada about 240,000 in a population of 1 million people would suffer fatal cancers from other causes (DIRS 153066-Murphy 2000, p. 83).

Traffic Fatalities

The analysis estimated traffic fatalities from accidents involving the transport of spent nuclear fuel and high-level radioactive waste by legal-weight trucks in Nevada for the mostly legal-weight truck scenario for shipments of the materials included in Inventory Modules 1 and 2. It estimated that there would be

Table J-60. Accident impacts for Modules 1 and 2 – Nevada transportation.[a]

Transportation scenario	Dose risk (person-rem)	Latent cancer fatalities	Traffic fatalities
Legal-weight truck	0.1[b]	0.0001	0.97
Legal-weight truck for the mostly rail scenario	0.003	0.000001	0.03
Mostly rail (Nevada rail implementing alternatives)			
Caliente	0.0012	0.000001	0.12
Carlin	0.0026	0.000001	0.16
Caliente-Chalk Mountain	0.0011	0.000001	0.08
Jean	0.01	0.000005	0.09
Valley Modified	0.0017	0.000001	0.08
Mostly rail (Nevada heavy-haul implementing alternatives)			
Caliente	0.015	0.000008	1.2
Caliente/Chalk Mountain	0.002	0.000001	0.62
Caliente/Las Vegas	0.092	0.00005	0.83
Apex/Dry Lake	0.091	0.00005	0.44
Sloan/Jean	0.2	0.0001	0.46

a. Impacts over 38 years.
b. Estimates of dose risk are for the transportation of the materials included in Module 2. Estimates of dose risk for transportation of the materials in Module 1 would be slightly (about 3 percent) lower.

0.97 fatality over 38 years for Module 1 or Module 2 (see Table J-60). The estimate of traffic fatalities includes the risk of fatalities from 300 shipments of naval spent nuclear fuel.

J.3.5.2 Nevada Rail Implementing Alternatives

Industrial Safety Impacts

Table J-61 lists the estimated industrial safety impacts in Nevada for the operation of a branch rail line to ship the materials included in Inventory Modules 1 and 2. The table lists impacts that would result from operations for a branch line in each of the five possible rail corridors in Nevada that DOE is evaluating.

Table J-61. Rail corridor operation worker physical trauma impacts (Modules 1 and 2).

Worker group and impact category	Corridor				
	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Involved workers					
TRC[a]	150	150	150	115	115
LWC[b]	82	82	82	63	63
Fatalities	0.41	0.41	0.41	0.31	0.31
Noninvolved workers[c]					
TRC	9	9	9	7	7
LWC	3	3	3	2	2
Fatalities	0.01	0.01	0.01	0.01	0.01
All workers (totals)[d]					
TRC	160	160	160	120	120
LWC	85	85	85	65	65
Fatalities	0.42	0.42	0.42	0.32	0.32
Traffic fatalities[e]	1.1	1.1	1.1	0.83	0.83

a. TRC = total recordable cases (injury and illness).
b. LWC = lost workday cases.
c. Noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
d. Totals might differ from sums due to rounding.
e. Fatalities from accidents during commutes to and from jobs for involved and noninvolved workers.

The representative workplace loss incidence rate for each impact parameter (as compiled by the Bureau of Labor Statistics) was used as a multiplier to convert the operations crew level of effort to expected industrial safety losses. The involved worker full-time equivalent multiples that DOE would assign to operate each rail corridor each year was estimated to be 36 to 47 full-time equivalents, depending on the corridor for the period of operations [scaled from cost data in DIRS 101214-CRWMS M&O (1996, Appendix E)]. Noninvolved worker full-time equivalent multiples were unavailable, so DOE assumed that the noninvolved worker level of effort would be similar to that for the repository operations work force—about 25 percent of that for involved workers. The Bureau of Labor Statistics loss incidence rate for each total recordable case, lost workday, and fatality trauma category (for example, the number of total recordable cases per full-time equivalent) was multiplied by the involved and noninvolved worker full-time equivalent multiples to project the associated trauma incidence.

The Bureau of Labor Statistics involved worker total recordable case incidence rate, 145,700 total recordable cases in a workforce of 1,739,000 workers (0.084 total recordable case per full-time equivalent) reflects losses in the Trucking and Warehousing sector during the 1998 period of record. The same Bureau of Labor Statistics period of record and industry sector was used to select the involved worker lost workday case incidence rate [80,000 lost workday cases in a workforce of 1,739,000 workers (0.046 lost workday case per full-time equivalent)]. The involved worker fatality incidence rate, 23.4 fatalities in a workforce of 100,000 workers (0.00023 fatality per full-time equivalent) reflects losses in the Transportation and Material Moving Occupations sector during the 1998 period of record.

The noninvolved worker total recordable case incidence rate of 61,000 total recordable cases in a workforce of 3,170,300 workers (0.019 total recordable case per full-time equivalent) reflects losses in the Engineering and Management Services sector during the Bureau of Labor Statistics 1998 period of record. DOE used the same period of record and industry sector to select the noninvolved worker lost workday case incidence rate [22,400 lost workday cases in a workforce of 3,170,300 workers (0.071 lost workday case per full-time equivalent)]. The noninvolved worker fatality incidence rate, 1.6 fatalities in a workforce of 100,000 workers (0.00002 fatality per full-time equivalent) reflects losses in the Managerial and Professional Specialties sector during the 1998 period of record.

Table J-61 lists the results of these industrial safety calculations for the five candidate corridors under Inventory Modules 1 and 2. The table also lists estimates of the number of traffic fatalities that would occur in the course of commuting by workers to and from their construction and operations jobs. These estimates used national statistics for average commute distances [18.5 kilometers (11.5 miles) one-way (DIRS 102064-FHWA 1999, all)] and fatality rates for automobile traffic [1 per 100 million kilometers (1.5 per 100 million miles) (DIRS 148080-BTS 1998, all)].

Radiological Impacts of Accidents

The analysis estimated the radiological impacts of accident scenarios in Nevada for the Nevada rail implementing alternatives for shipments of the materials included in Inventory Modules 1 and 2. Table J-60 lists the radiological dose risk and associated risk of latent cancer fatalities. The risks include accident risks in Nevada from approximately 3,100 legal-weight truck shipments from commercial sites that could not ship spent nuclear fuel in rail casks while operational. The analysis assumed that those sites would upgrade their crane capacity after reactor shutdown to allow the use of rail casks. The risks would occur over 38 years.

Traffic Fatalities

Traffic fatalities from accidents involving transport of spent nuclear fuel and high-level radioactive waste by rail in Nevada were estimated for the Nevada rail implementing alternatives for shipments of materials included in Inventory Modules 1 and 2. Table J-60 lists the estimated number of fatalities that would occur over 38 years for a branch rail line along each of the five candidate rail corridors. These estimates include accident risks in Nevada from about 3,100 legal-weight truck shipments from commercial generators that could not ship spent nuclear fuel in rail casks while operational.

J.3.5.3 Nevada Heavy-Haul Truck Implementing Alternatives

Industrial Safety Impacts

Tables J-62 and J-63 list the estimated industrial safety impacts in Nevada for operations of heavy-haul trucks (principally highway maintenance safety impacts) and operation of an intermodal transfer station that would transfer loaded and unloaded rail casks between rail cars and heavy-haul trucks for shipments of the materials included in Inventory Modules 1 and 2. Table J-62 lists the estimated industrial safety impacts in Nevada for the operation of a heavy-haul route to the Yucca Mountain site. Table J-63 lists impacts that would result from the operation of an intermodal transfer station for any of the five candidate routes DOE is evaluating that heavy-haul trucks could use in Nevada.

Table J-62. Industrial health impacts from heavy-haul truck route operations (Modules 1 and 2).

Worker group and impact category	Corridor				
	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/ Jean	Apex/Dry Lake
Involved workers					
TRC[a]	350	350	320	190	190
LWC[b]	190	190	180	100	100
Fatalities	1.0	1.0	0.9	0.5	0.5
Noninvolved workers[c]					
TRC	20	20	18	11	11
LWC	8	8	7	4	4
Fatalities	0.02	0.02	0.02	0.01	0.01
All workers (totals)[d]					
TRC	370	370	340	200	200
LWC	200	200	180	110	110
Fatalities	0.99	0.99	0.99	0.53	0.53
Traffic fatalities[e]	2.6	2.3	2.6	1.4	1.4

a. TRC = total recordable cases (injury and illness).
b. LWC = lost workday cases.
c. Noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
d. Totals might differ from sums due to rounding.
e. Fatalities from accidents during commutes to and from jobs for involved and noninvolved workers.

Table J-63. Annual physical trauma impacts to workers from intermodal transfer station operations (Module 1 or 2).

Involved workers			Noninvolved workers[a]			All workers		
TRC[b]	LWC[c]	Fatalities	TRC	LWC	Fatalities	TRC	LWC	Fatalities
85	47	0.23	5	2	0.01	90	48	0.24

a. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
b. TRC = total recordable cases of injury and illness.
c. LWC = lost workday cases.

Radiological Impacts of Accidents

The analysis estimated the radiological impacts of accidents in Nevada for the Nevada heavy-haul truck implementing alternatives for shipments of the materials included in Inventory Modules 1 and 2.

Table J-60 lists the radiological dose risk and associated risk of latent cancer fatalities. The risks include accident risks in Nevada from approximately 3,100 legal-weight truck shipments from commercial generating sites that could not ship spent nuclear fuel in rail casks while operational. The risk would occur over 38 years.

Traffic Fatalities

The analysis estimated traffic fatalities from accidents involving the transport of spent nuclear fuel and high-level radioactive waste (including the rail portion of transportation to and from an intermodal transfer station) in Nevada for the heavy-haul truck implementing alternatives for shipments of the materials included in Inventory Modules 1 and 2. Table J-60 lists the estimated number of fatalities that would occur over 38 years for a branch rail line and for each of the five candidate routes for heavy-haul trucks. The estimate for traffic fatalities includes accident risk in Nevada from about 3,100 legal-weight truck shipments from commercial generators that could not ship spent nuclear fuel in rail casks while operational.

J.3.6 IMPACTS FROM TRANSPORTATION OF OTHER MATERIALS

Other types of transportation activities associated with the Proposed Action would involve shipments of materials other than the spent nuclear fuel and high-level radioactive waste discussed in previous sections. These activities would include the transportation of people (commuter transportation). This section evaluates occupational and public health and safety and air quality impacts from the shipment of:

- Construction materials, consumables, and personnel for repository construction and operation, including repository components (disposal containers, emplacement pallets, drip shields, and solar panels).
- Waste including low-level waste, construction and demolition debris, sanitary and industrial solid waste, and hazardous waste
- Office and laboratory supplies, mail, and laboratory samples

The analysis included potential impacts of transporting these materials for the flexible design, in which the repository would be open for 76 years after emplacement, and for several lower-temperature operating scenarios that would leave the repository open and ventilated for 125 to 300 years, a surface facility that would provide storage during a cooling period, and the use of derated waste packages. The analysis assumed that material would be shipped across the United States to Nevada by rail, but that DOE would not build a rail line to the proposed repository, because the larger number of truck shipments would lead to higher impacts than those for rail shipments, as discussed above. In addition, because the construction schedule for a new rail line would coincide with the schedule for the construction of repository facilities, trucks would deliver materials for repository construction.

Rail service would benefit the delivery of the 11,300 disposal containers from manufacturers. Two 33,000-kilogram (about 73,000-pound) disposal containers and their 700-kilogram (about 1,500-pound) lids (DIRS 155347-CRWMS M&O 1999, all) would be delivered on a railcar—a total of 5,650 railcar deliveries over the 24-year period of the Proposed Action (8,400 railcar deliveries if DOE used 17,000 derated waste packages). These containers would be delivered to the repository along with shipments of spent nuclear fuel and high-level radioactive waste or separately on supply trains along with shipments of materials and equipment.

Disposal container components that would weigh as much as 34 metric tons (37.5 tons) would be transported to Nevada by rail and transferred to overweight trucks for shipment to the repository site. Overweight truck shipments would move the 11,300 (or 17,000 if derated) containers from a railhead to the site. The State of Nevada routinely provides permits to motor carriers for overweight, overdimension loads if the gross vehicle weight does not exceed 58.5 metric tons (64.5 tons) (DIRS 155347-CRWMS M&O 1999, Request #046).

J.3.6.1 Transportation of Personnel and Materials to Repository

The following paragraphs describe impacts that would result from the transportation of construction materials, consumables, repository components, supplies, mail, laboratory samples, and personnel to the repository site during the construction, operation and monitoring, and closure phases of the Proposed Action.

Human Health and Safety

Most construction materials, construction equipment, and consumables would be transported to the Yucca Mountain site on legal-weight trucks. Heavy and overdimensional construction equipment would be delivered by trucks under permits issued by the Nevada Department of Transportation. The analysis assumed that repository components would be manufactured somewhere in the central United States, while other materials and consumables would originate in Nevada. DOE estimates that about 37,000 to 41,000 rail and truck shipments over 5 years would be necessary to transport materials, supplies, and equipment to the site during the construction phase, depending on the operating mode. Surface facilities for aging would require more construction materials.

In addition to construction materials, supplies, equipment, and repository components, trucks would deliver consumables to the repository site. These would include diesel fuel, cement, and other materials that would be consumed in daily operations.

Over the 24-year period of operation, the repository would receive between 6,600 and 10,000 shipments from across the United States, and between 47,000 and 62,000 shipments in Nevada of supplies, materials, equipment, repository components, and consumables, including cement and other materials for underground excavation. The analysis assumed that the Nevada shipments would originate in the Las Vegas metropolitan area. In addition, an estimated 53,000 shipments of office and laboratory supplies and equipment, mail, and laboratory samples would occur during the 24 years of operation. About 27 million to 41 million vehicle kilometers nationally (17 million to 25 million vehicle miles) of travel, and about 34 million to 40 million kilometers (21 million to 25 million miles) in Nevada would be involved. Impacts would include vehicle emissions, consumption of petroleum resources, increased truck traffic on regional highways, and fatalities from accidents. Similarly, there would be about 43 to 760 shipments nationally, and 190,000 to 720,000 shipments in Nevada during the 76-to-300-year monitoring period after emplacement operations and about 35,000 shipments, more than 99 percent in Nevada, during closure activities. Table J-64 summarizes these impacts.

Table J-64. Human health and safety impacts from national and Nevada shipments of material to the repository.

Phase	Kilometers[a] traveled (millions)	Traffic fatalities	Fuel consumption (millions of liters)[b]	Vehicle emissions-related fatalities
Construction (5 years)	8.9 - 10	0.15 - 0.21	2.9 - 10	0.019 - 0.022
Emplacement and development (24 years)	61 - 81	2.7 - 3.9	430 - 650	0.14 - 0.19
Monitoring (76 to 300 years)	47 - 170	0.8 - 3.0	13 - 65	0.10 - 0.36
Closure (10 to 17 years)	8.4 - 8.9	0.14 - 0.17	2.2 - 8.1	0.018 - 0.019
Totals[c]	*130 - 270*	*3.8 - 7.2*	*450 - 720*	*0.27 - 0.59*

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. Totals might not equal sums due to rounding.

During the construction phase, many employees would use their personal automobiles to travel to construction areas on the repository site and to highway or rail line construction sites. The estimated average annual level of direct employment during repository surface and subsurface construction would be between 1,500 and 1,600 workers, depending on the operating mode. Current Nevada Test Site employees can ride DOE-provided buses to and from work; similarly, buses probably would be available for repository construction workers. The use of buses and car pools would result in an average vehicle occupancy of 8.6 persons per vehicle. Table J-65 summarizes the anticipated number of traffic-accident-related injuries and fatalities and the estimated consumption of gasoline that would occur from this travel activity. The greatest impact of this traffic would be added congestion at the northwestern Las Vegas Beltway interchange with U.S. Highway 95. Current estimates call for traffic at this interchange during rush hours to be as high as 1,000 vehicles an hour (DIRS 103710-Clark County 1997, Table 3-12, p. 3-43). The additional traffic from repository construction, assuming that the peak traffic would be 3 times the average, would be an estimated 600 vehicles per hour and would add about 35 percent to traffic volume at peak rush hour and would contribute to congestion although congestion in this area would be generally low.

Table J-65. Health impacts and fuel consumption from transportation of construction and operations workers.

Phase	Kilometers[a] traveled (in millions)	Traffic fatalities	Fuel consumption (millions of liters)[b]	Vehicle emissions-related fatalities
Construction	51 - 56	0.51 - 0.56	8.5 - 8.7	0.067 - 0.074
Emplacement and development (24 years)	290 - 440	2.9 - 4.4	48 - 73	0.38 - 0.58
Monitoring (76 to 300 years)	87 - 280	0.87 - 2.8	14 - 45	0.11 - 0.36
Closure	48 - 62	0.48 - 0.62	8.0 - 10	0.063 - 0.082
Totals[c]	*480 - 800*	*4.8 - 8.0*	*79 - 130*	*0.63 - 1.1*

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. Totals might not equal sums due to rounding.

The average annual employment during emplacement and development operations would be between 1,700 and 2,600 workers. As mentioned above, DOE provides bus service from the Las Vegas area to and from the Nevada Test Site. Table J-65 summarizes the anticipated number of traffic-accident-related fatalities and the estimated consumption of gasoline that would occur from this travel activity. The greatest impact of this traffic would be increased congestion at the northwestern Las Vegas Beltway interchange with U.S. 95. As many as 600 to 850 vehicles an hour at peak rush hour would contribute to the congestion. Approximately 130 to 160 people would be employed annually during monitoring and about 460 to 600 would be employed annually during closure. The number of vehicles associated with these levels of employment, about 70 at most, would contribute negligibly to congestion.

Table J-66 lists the impacts associated with the delivery of fabricated disposal container components from a manufacturing site to the repository. A total of 11,300 containers (17,000 under the derated waste package scenario) would be delivered; if a rail line to Yucca Mountain was not available, the mode of transportation would be a combination of rail and overweight truck. The analysis assumes that the capacity of each railcar would be two containers and that the capacity of a truck would be one container, so there would be 5,650 railcar shipments to Nevada and 11,300 truck shipments to the Yucca Mountain site (8,400 rail shipments and 17,000 truck shipments if derated waste packages were used). The analysis estimated impacts for one national rail route representing a potential route from a manufacturing facility to a Nevada rail siding. The analysis estimated the impacts of transporting the containers from this siding over a single truck route—the Apex/Dry Lake route analyzed for the transportation of spent nuclear fuel and high-level radioactive waste by heavy-haul trucks. Although the actual mileage from a manufacturing facility could be shorter, DOE decided to select a distance that represents a conservative

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Table J-66. Impacts of disposal container shipments for 24 years of the Proposed Action.[a]

Type of shipment	Number of shipments	Vehicle emissions-related health effects	Traffic fatalities
Rail and truck	5,650 - 8,400 rail/ 11,300 - 17,000 truck	0.088 - 0.13	2.2 - 3.2

a. Impacts of transporting drip shields and emplacement pallets are included in results listed in Table J-64.

estimate [4,439 kilometers (2,758 miles)]. The impacts are split into two subcategories—health effects from vehicle emissions and fatalities from transportation accidents.

Air Quality

The exhaust from vehicles involved in the transport of personnel and materials to the repository would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter (PM_{10}). Because carbon monoxide is the principal pollutant of interest for evaluating impacts caused by motor vehicle emissions, the analysis focused on it. Table J-67 indicates the basis for selecting carbon monoxide as the principal pollutant of concern.

Table J-67. Listed pollutants and pollutant of interest.

Listed pollutant	Gasoline emissions	Diesel emissions
Carbon monoxide	Total emissions into the basin are larger than for diesel	More per vehicle-mile, but total emissions are less
Sulfur dioxide	Very minor problem with modern gasoline	Emits slightly more than gasoline
Nitrogen oxides	Limit less restrictive than carbon monoxide limit	
Particulate matter	Dust,[b] asphalt, and combustion particles	
Ozone	Limit less restrictive than carbon monoxide limit[c]	
Lead	Not a problem with modern gasoline	Does not produce lead

a. Source: 40 CFR 93.153.
b. Of most concern from earthmoving rather than fuel emissions (see DIRS 155557-Clark County 2001, all).
c. Ozone is not an emission but a product of sunlight acting on hydrocarbons and nitrogen oxides.

The analysis assumed that most of the personnel who would commute to the repository would reside in the Las Vegas area and that most of the materials would travel to the repository from the Las Vegas area. To estimate maximum potential emissions to the Las Vegas Valley airshed, which is in nonattainment for carbon monoxide (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54), the analysis assumed that all personnel and material would travel from the center of Las Vegas to the repository. Table J-68 lists the estimated annual amount of carbon monoxide that would be emitted to the valley airshed during the phases of the repository project and the percent of the corresponding threshold level. Although it can be a health hazard (see Table J-65), its emission rate in the Las Vegas basin would be below the standard.

Table J-68. Annual range of carbon monoxide emitted to Las Vegas Valley airshed from transport of personnel and material to repository (kilograms per year)[a] for all modes of the Proposed Action.

Phase	Annual emission rate	Percent of GCR threshold level[b]
Construction	41,000 - 45,000	45 - 50
Emplacement and development	44,000 - 62,000	49 - 69
Operations and monitoring period	6,400 - 8,200	7 - 9
Closure	33,000 - 39,000	36 - 43

a. To convert kilograms to tons, multiply by 0.0011023.
b. GCR = General Conformity Rule; the emission threshold level for carbon monoxide in a nonattainment area is 91,000 kilograms (100 tons) per year (40 CFR 93.153).

As listed in Table J-68, the annual amount of carbon monoxide emitted to the nonattainment area would be below the threshold level during all phases of the Proposed Action. In the operation phase, the estimated annual amount of carbon monoxide emitted would be greatest (49 to 69 percent) to the threshold level. Relative to the vehicle emissions from the repository-bound high-level radioactive waste and spent nuclear fuel, the emissions from the transport of personnel and materials is substantially greater for all transportation implementing alternatives.

DOE conducted a conformity review using the guidance in DIRS 155566-DOE (2000, all) to estimate carbon monoxide emissions from the transportation of personnel, materials, and supplies through the Las Vegas air basin under each transportation implementing alternative. The transportation of personnel, materials, and supplies would be the main repository-related contributor of carbon monoxide to the nonattainment area. Compared to the total from all sources in the nonattainment area, the transportation of personnel, materials, and supplies to Yucca Mountain would add, at most, an additional 0.07 percent to the 2000 daily levels of carbon monoxide in the air basin (DIRS 156706-Clark County 2000, Appendix A, Table 1-3).

For areas that are in attainment, pollutant concentrations in the ambient air probably would increase due to the additional traffic but, given the relatively small amount of traffic that passes through these areas, the additional traffic would be unlikely to cause the ambient air quality standards to be exceeded.

Noise

Traffic-related noise on major transportation routes used by the workforce would likely increase. The analysis of impacts from traffic noise assumed that the workforce would come from Nye County (20 percent) and Clark County (80 percent). During the period of maximum employment in 2015, the analysis estimated a daily maximum of 576 vehicles would pass through the Gate 100 entrance at Mercury during rush hour [compared to a baseline of 232 vehicles per hour (DIRS 101811-DOE 1996, pp. 4-43 and 4-45)]. One-hour equivalent rush hour noise levels resulting from increased traffic would increase by 3.4 dBA at Indian Springs and 4.4 dBA at Mercury over background noise levels of 66.6 and 65.5 dBA, respectively. The increase could be perceptible to the community but, because of its short duration and existing highway noise, would be unlikely to result in an adverse public response.

J.3.6.2 Impacts of Transporting Wastes from the Repository

During repository construction and operations, DOE would ship waste and sample material from the repository. The waste would include hazardous, mixed, and low-level radioactive waste. Samples would include radioactive and nonradioactive hazardous materials shipped to laboratories for analysis. In addition, nonhazardous solid waste could be shipped from the repository site to the Nevada Test Site for disposal. However, as noted in Chapter 2, DOE proposes to include an industrial landfill on the repository site. Table J-69 summarizes the health impacts from wastes that DOE would ship from the repository.

Table J-69. Health impacts and fuel consumption from transportation of waste from the Yucca Mountain repository.

Phase	Kilometers[a] traveled (in millions)	Traffic fatalities	Fuel consumption (millions of liters)[b]	Vehicle emissions-related fatalities
Construction	0.37 - 0.39	0.0061 - 0.0066	0.086 - 0.092	0.00077 - 0.0082
Emplacement and development (24 years)	2.8 - 3.1	0.047 - 0.051	0.67 - 0.72	0.0040 - 0.0043
Monitoring (76 to 300 years)	1.8 - 6.2	0.031 - 0.10	0.44 - 1.5	0.0026 - 0.0088
Closure	0.67 - 0.88	0.011 - 0.020	0.16 - 0.24	0.0014 - 0.0025
Totals [c]	6.1 - 11	0.10 - 0.18	1.4 - 2.5	0.0093 - 0.016

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. Totals might not equal sums due to rounding.

Occupational and Public Health and Safety

The quantities of hazardous waste that DOE would ship to approved facilities off the Nevada Test Site would be relatively small and would present little risk to public health and safety. This waste could be shipped by rail (if DOE built a rail line to the repository site) or by legal-weight truck to permitted disposal facilities. The principal risks associated with shipments of these materials would be related to traffic accidents. These risks would include 0.01 fatality for the combined construction, operation and monitoring, and closure phases for hazardous wastes.

DOE probably would ship low-level radioactive waste by truck to existing disposal facilities on the Nevada Test Site. Although these shipments would not use public highways, DOE estimated their risks. As with shipments of hazardous waste, the principal risk in transporting low-level radioactive waste would be related to traffic accidents. Because traffic on the Nevada Test Site is regulated by the Nye County Sheriff's Department, DOE assumed that accident rates on the site are similar to those of secondary highways in Nevada. Low-level radioactive waste would not be present during the construction of the repository. Therefore, accidents involving such waste could occur only during the operation and monitoring and the closure phases, although most of this waste would be generated during the construction and operation and monitoring phases. DOE estimates between 0.0038 and 0.0053 traffic fatality from the transportation of low-level radioactive waste during the repository construction, operation and monitoring, and closure phases. Table J-69 lists the impacts of transporting wastes, including hazardous waste, sanitary waste, construction debris, and low-level radioactive waste.

Air Quality

The quantities of hazardous waste that DOE would ship to approved facilities off the Nevada Test Site would be relatively small. Vehicle emissions due to these shipments would present little risk to public health and safety.

Biological Resources and Soils

The transportation of people, materials, and wastes during the construction, operation and monitoring, and closure phases of the repository could involve between 610 and 1,100 million vehicle-kilometers (between 380 and 680 million vehicle-miles) of travel on highways in southern Nevada depending on the repository operating mode. This travel would use existing highways that pass through desert tortoise habitat. Individual desert tortoises probably would be killed. However, because populations of the species are low in the vicinity of the routes (DIRS 103160-Bury and Germano 1994, pp. 57 to 72), few would be lost. Thus, the loss of individual desert tortoises due to repository traffic would not be likely to be a threat to the conservation of this species. In accordance with requirements of Section 7 of the Endangered Species Act (16 U.S.C. 1531 *et seq.*), DOE would consult with the Fish and Wildlife Service and would comply with mitigation measures resulting from that consultation to limit losses of desert tortoises from repository traffic.

J.3.6.3 Impacts from Transporting Other Materials and People in Nevada for Inventory Modules 1 and 2

The analysis evaluated impacts to occupational and public health and safety in Nevada from the transport of materials, wastes, and workers (including repository-related commuter travel) for construction, operation and monitoring, and closure of the repository that would occur for the receipt and emplacement of materials in Inventory Modules 1 and 2. The analysis assumed that the routes and transportation characteristics (for example, accident rates) for transportation associated with the Proposed Action and Inventory Modules 1 and 2 would be the same. The only difference would be the projected number of trips for materials, wastes, and workers traveling to the repository.

Table J-70 lists estimated incident-free (vehicle emissions) impacts and traffic (accident) fatality impacts in Nevada for the transportation of materials, wastes, and workers (including repository-related commuter travel) for the construction, operation and monitoring, and closure of the repository that would occur for the receipt and emplacement of the materials in Inventory Modules 1 and 2. The range includes all lower-temperature repository operating mode scenarios.

Table J-70. Health impacts from transportation of materials, consumables, personnel, and waste for Modules 1 and 2.[a]

Phase	Kilometers traveled (millions)[b]	Traffic fatalities	Emission-related health effects
Construction	61 - 67	0.67 - 0.74	0.086 - 0.096
Emplacement and Development	510 - 640	8.5 - 9.8	0.78 - 0.92
Operation and Monitoring	150 - 480	1.9 - 6.1	0.24 - 0.79
Closure	59 - 97	0.65 - 1.0	0.084 - 0.13
Totals	***820 - 1,200***	***12 - 18***	***1.2 - 1.9***

a. Numbers are rounded.
b. To convert kilometers to miles, multiply by 0.62137.
c. Totals might not equal sums due to rounding.

Even with the increased transportation of the other materials included in Module 1 or 2, DOE expects that the transportation of materials, consumables, personnel, and waste to and from the repository would be minor contributors to all transportation on a local, state, and national level. Public and worker health impacts would be small from transportation accidents involving nonradioactive hazardous materials. On average, in the United States there is about 1 fatality caused by the hazardous material being transported for each 30 million shipments by all modes (DIRS 103717-DOT 1998, p. 1; DIRS 103720-DOT Undated, Exhibit 2b).

J.4 State-Specific Impacts and Route Maps

This section contains maps and tables that illustrate the estimated impacts to 45 states and the District of Columbia (Alaska and Hawaii are not included; estimated impacts in Montana, North Dakota, and Rhode Island would be zero). As discussed previously in this appendix, DOE used state- and route-specific data to estimate transportation impacts. At this time, about 10 years before shipments could begin, DOE has not determined the specific routes it would use to ship spent nuclear fuel and high-level radioactive waste to the proposed repository. Therefore, the transportation routes discussed in this section might not be the exact routes actually used for shipments to Yucca Mountain. Nevertheless, because the analysis is based primarily on the existing Interstate Highway System and rail rolling stock, the analysis presents a representative estimate of what the actual transportation impacts would likely be.

In addition, under the national mostly rail transportation scenario, potential impacts in each state vary according to the ending node in Nevada. There are six different points of transfer from national to Nevada transportation (Caliente, Dry Lake, Jean, Beowawe, Eccles, and Apex). The routes used in the national analysis depend on the transfer point through which the shipments would pass. Tables J-71 through J-92 list the transportation impacts for 47 of the states and the District of Colombia, and Figures J-31 through J-52 are maps of the routes analyzed for each region.

In Nevada, the impacts vary according to the rail or heavy-haul implementing alternative. Figure J-53 shows the potential routes in the State of Nevada, and Table J-93 lists the impacts in Nevada for each of the eight implementing alternatives.

Table J-71. Estimated transportation impacts for the States of Alabama and Georgia.

State and impact category	Mostly legal-weight truck	Mostly rail — Ending rail node in Nevada[a]: Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
ALABAMA							
Shipments							
Truck (originating/total)	1,755/1,755	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	283/2,413	283/2,413	283/2,413	283/2,413	283/2,413	283/2,413
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$5.0\times10^{0}/2.5\times10^{-3}$	$3.7\times10^{1}/1.8\times10^{-3}$	$3.7\times10^{1}/1.8\times10^{-3}$	$4.9\times10^{0}/2.4\times10^{-3}$	$3.7\times10^{1}/1.8\times10^{-3}$	$3.7\times10^{1}/1.8\times10^{-3}$	$3.7\times10^{1}/1.8\times10^{-3}$
Workers (person-rem/LCFs)	$4.2\times10^{1}/1.7\times10^{-2}$	$2.1\times10^{1}/8.2\times10^{-3}$	$2.1\times10^{1}/8.2\times10^{-3}$	$2.2\times10^{1}/8.8\times10^{-3}$	$2.1\times10^{1}/8.2\times10^{-3}$	$2.1\times10^{1}/8.2\times10^{-3}$	$2.1\times10^{1}/8.2\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$4.6\times10^{-4}/2.3\times10^{-7}$	$3.1\times10^{-4}/1.5\times10^{-7}$	$3.1\times10^{-4}/1.5\times10^{-7}$	$7.0\times10^{-4}/3.5\times10^{-7}$	$3.1\times10^{-4}/1.5\times10^{-7}$	$3.1\times10^{-4}/1.5\times10^{-7}$	$3.1\times10^{-4}/1.5\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.0×10^{-3}	8.4×10^{-4}	8.4×10^{-4}	1.4×10^{-3}	8.4×10^{-4}	8.4×10^{-4}	8.4×10^{-4}
Fatalities	0.003	0.009	0.009	0.011	0.009	0.009	0.009
GEORGIA							
Shipments							
Truck (originating/total)	1,664/13,169	0/491	0/491	0/491	0/491	0/491	0/491
Rail (originating/total)	0/0	321/2,561	321/2,561	321/2,359	321/2,561	321/2,561	321/2,561
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.2\times10^{2}/1.1\times10^{-1}$	$1.0\times10^{2}/5.0\times10^{-2}$	$1.0\times10^{2}/5.0\times10^{-2}$	$9.4\times10^{1}/4.7\times10^{-2}$	$1.0\times10^{2}/5.0\times10^{-2}$	$1.0\times10^{2}/5.0\times10^{-2}$	$1.0\times10^{2}/5.0\times10^{-2}$
Workers (person-rem/LCFs)	$4.0\times10^{2}/1.6\times10^{-1}$	$1.2\times10^{2}/4.8\times10^{-2}$	$1.2\times10^{2}/4.8\times10^{-2}$	$1.1\times10^{2}/4.4\times10^{-2}$	$1.2\times10^{2}/4.8\times10^{-2}$	$1.2\times10^{2}/4.8\times10^{-2}$	$1.2\times10^{2}/4.8\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$5.6\times10^{-2}/2.8\times10^{-5}$	$1.4\times10^{-2}/7.2\times10^{-6}$	$1.4\times10^{-2}/7.2\times10^{-6}$	$1.2\times10^{-2}/6.1\times10^{-6}$	$1.4\times10^{-2}/7.2\times10^{-6}$	$1.4\times10^{-2}/7.2\times10^{-6}$	$1.4\times10^{-2}/7.2\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	6.4×10^{-2}	4.8×10^{-2}	4.8×10^{-2}	4.4×10^{-2}	4.8×10^{-2}	4.8×10^{-2}	4.8×10^{-2}
Fatalities	0.22	0.10	0.10	0.09	0.10	0.10	0.10

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.

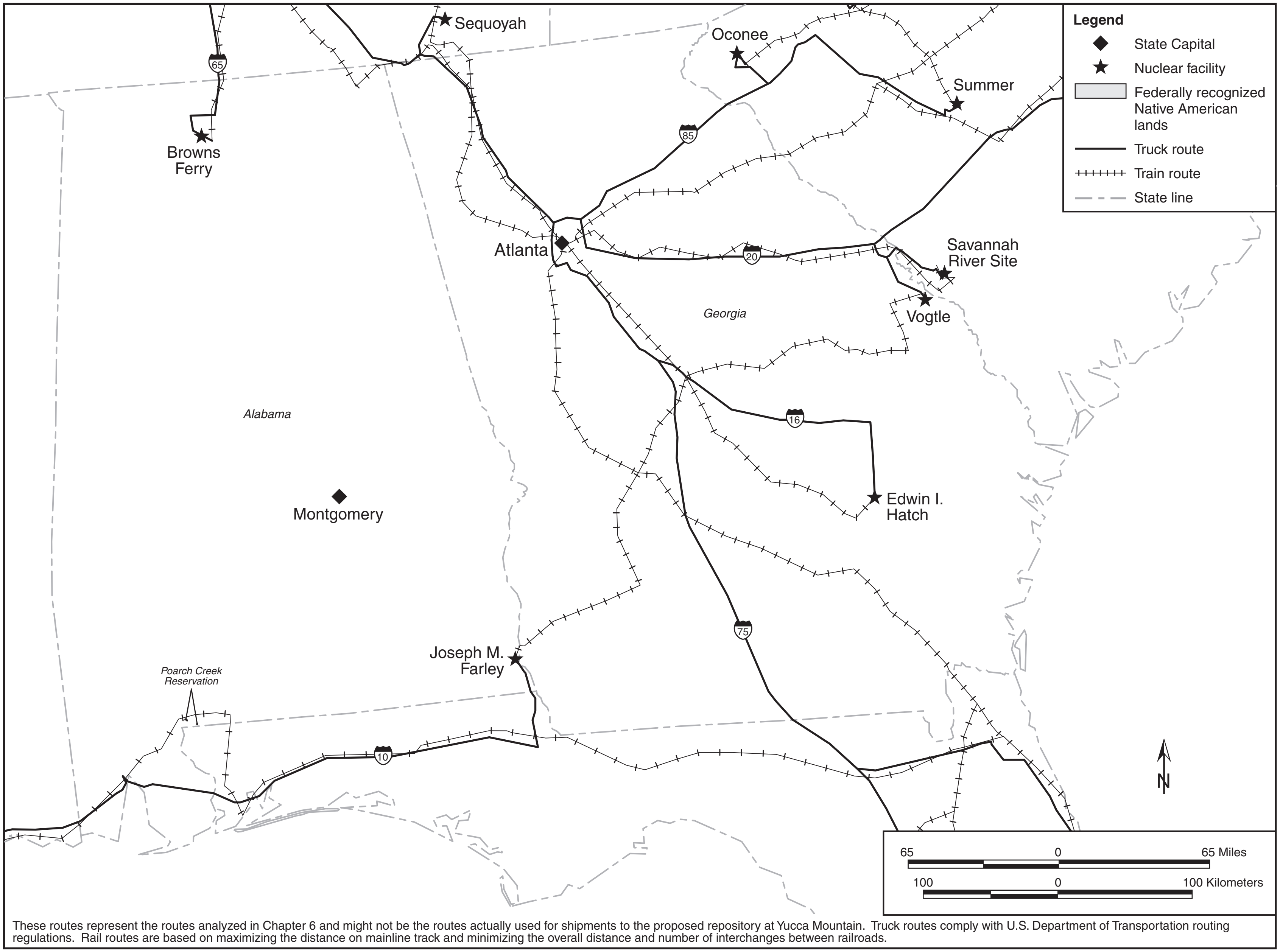


Figure J-31. Highway and rail routes used to analyze transportation impacts - Alabama and Georgia.

Table J-72. Estimated transportation impacts for the State of Arkansas.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
ARKANSAS							
Shipments							
Truck (originating/total)	794/794	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	121/201	121/201	121/121	121/258	121/201	121/201
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.3\times10^{0}/1.1\times10^{-3}$	$1.1\times10^{0}/5.4\times10^{-4}$	$1.1\times10^{0}/5.4\times10^{-4}$	$9.5\times10^{-1}/4.8\times10^{-4}$	$1.2\times10^{0}/5.8\times10^{-4}$	$1.1\times10^{0}/5.4\times10^{-4}$	$1.1\times10^{0}/5.4\times10^{-4}$
Workers (person-rem/LCFs)	$2.1\times10^{1}/8.3\times10^{-3}$	$7.8\times10^{0}/3.1\times10^{-3}$	$7.8\times10^{0}/3.1\times10^{-3}$	$6.6\times10^{0}/2.6\times10^{-3}$	$8.7\times10^{0}/3.5\times10^{-3}$	$7.8\times10^{0}/3.1\times10^{-3}$	$7.8\times10^{0}/3.1\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$4.6\times10^{-5}/2.3\times10^{-8}$	$3.8\times10^{-4}/1.9\times10^{-7}$	$3.8\times10^{-4}/1.9\times10^{-7}$	$2.4\times10^{-4}/1.2\times10^{-7}$	$4.7\times10^{-4}/2.4\times10^{-7}$	$3.8\times10^{-4}/1.9\times10^{-7}$	$3.8\times10^{-4}/1.9\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.9×10^{-4}	2.0×10^{-4}	2.0×10^{-4}	1.3×10^{-4}	2.4×10^{-4}	2.0×10^{-4}	2.0×10^{-4}
Fatalities	1.2×10^{-3}	3.7×10^{-3}	3.7×10^{-3}	1.6×10^{-3}	5.3×10^{-3}	3.7×10^{-3}	3.7×10^{-3}

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

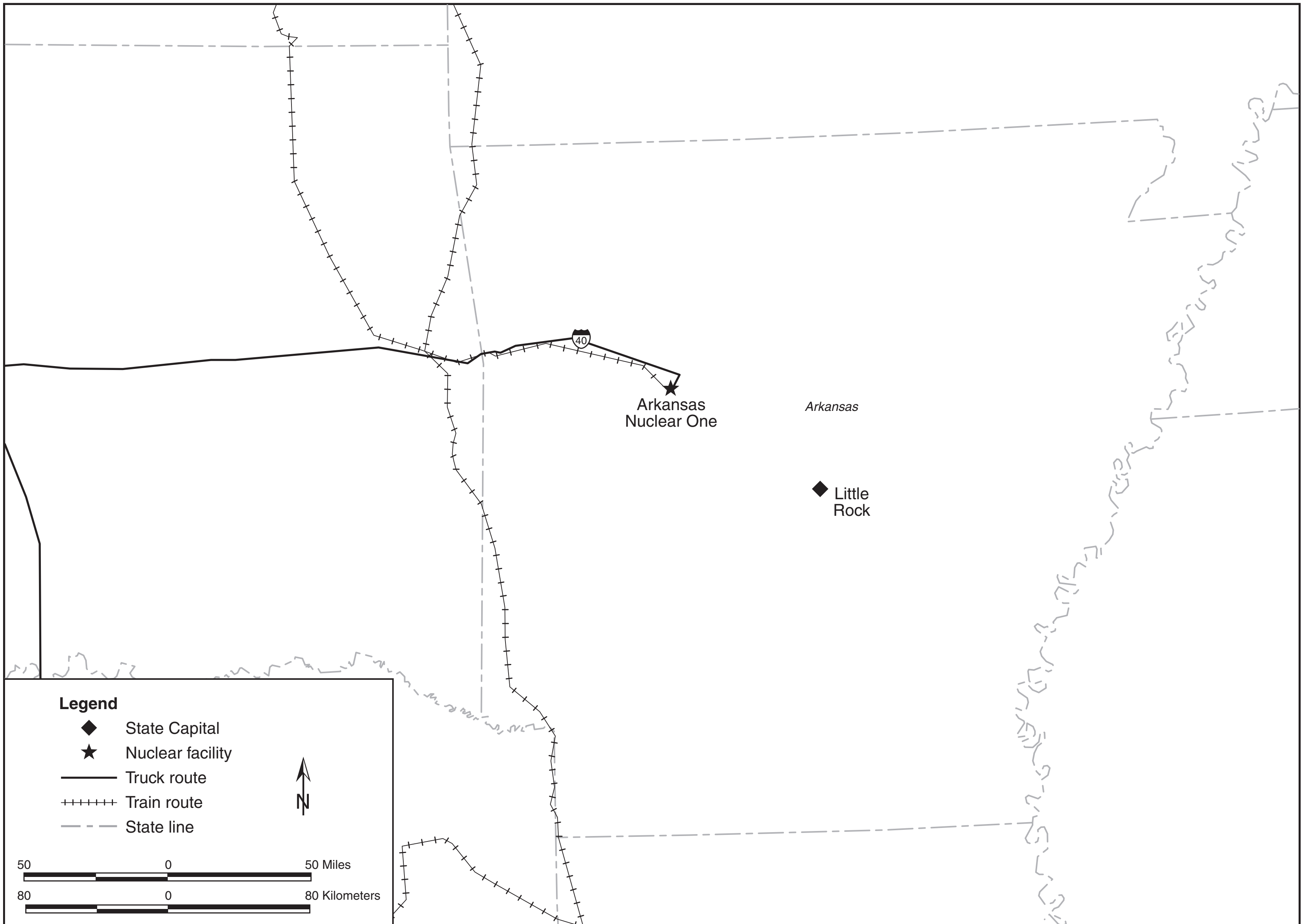
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-32. Highway and rail routes used to analyze transportation impacts - Arkansas.

Table J-73. Estimated transportation impacts for the States of Arizona and New Mexico.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
ARIZONA							
Shipments							
Truck (originating/total)	1,118/51,036	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079
Rail (originating/total)	0/0	193/374	193/431	193/1,145	193/193	193/308	193/585
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$9.2\times10^{1}/4.6\times10^{-2}$	$5.5\times10^{0}/2.7\times10^{-3}$	$6.1\times10^{0}/3.1\times10^{-3}$	$1.3\times10^{1}/6.7\times10^{-3}$	$3.4\times10^{0}/1.7\times10^{-3}$	$4.7\times10^{0}/2.3\times10^{-3}$	$7.9\times10^{0}/4.0\times10^{-3}$
Workers (person-rem/LCFs)	$3.2\times10^{2}/1.3\times10^{-1}$	$2.3\times10^{1}/9.0\times10^{-3}$	$2.5\times10^{1}/1.0\times10^{-2}$	$5.5\times10^{1}/2.2\times10^{-2}$	$1.5\times10^{1}/6.0\times10^{-3}$	$2.0\times10^{1}/7.9\times10^{-3}$	$3.1\times10^{1}/1.3\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$1.2\times10^{-3}/6.1\times10^{-7}$	$3.6\times10^{-4}/1.8\times10^{-7}$	$4.7\times10^{-4}/2.3\times10^{-7}$	$1.7\times10^{-3}/8.5\times10^{-7}$	$3.8\times10^{-5}/1.9\times10^{-8}$	$2.3\times10^{-4}/1.2\times10^{-7}$	$6.7\times10^{-4}/3.4\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	6.2×10^{-3}	1.2×10^{-3}	1.5×10^{-3}	5.1×10^{-3}	1.1×10^{-4}	7.8×10^{-4}	2.4×10^{-3}
Fatalities	8.9×10^{-2}	7.8×10^{-3}	9.4×10^{-3}	2.9×10^{-2}	2.8×10^{-3}	6.0×10^{-3}	1.4×10^{-2}
NEW MEXICO							
Shipments							
Truck (originating/total)	0/3,999	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/181	0/238	0/952	0/154	0/115	0/392
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[b]	$5.5\times10^{1}/2.8\times10^{-2}$	$3.4\times10^{-1}/1.7\times10^{-4}$	$4.4\times10^{-1}/2.2\times10^{-4}$	$2.3\times10^{0}/1.2\times10^{-3}$	$9.2\times10^{-3}/4.6\times10^{-6}$	$2.1\times10^{-1}/1.1\times10^{-4}$	$7.3\times10^{-1}/3.6\times10^{-4}$
Workers (person-rem/LCFs)	$1.4\times10^{2}/5.8\times10^{-2}$	$3.1\times10^{0}/1.2\times10^{-3}$	$4.0\times10^{0}/1.6\times10^{-3}$	$2.3\times10^{1}/9.3\times10^{-3}$	$1.3\times10^{0}/5.2\times10^{-4}$	$1.9\times10^{0}/7.8\times10^{-4}$	$6.6\times10^{0}/2.7\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$1.6\times10^{-3}/8.2\times10^{-7}$	$3.9\times10^{-5}/2.0\times10^{-8}$	$5.3\times10^{-5}/2.7\times10^{-8}$	$3.0\times10^{-4}/1.5\times10^{-7}$	$1.2\times10^{-6}/6.1\times10^{-10}$	$2.4\times10^{-5}/1.2\times10^{-8}$	$7.9\times10^{-5}/3.9\times10^{-8}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.0×10^{-2}	1.9×10^{-4}	2.4×10^{-4}	1.3×10^{-3}	4.3×10^{-6}	1.2×10^{-4}	4.0×10^{-4}
Fatalities	0.053	0.001	0.002	0.010	0.001	0.001	0.003

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

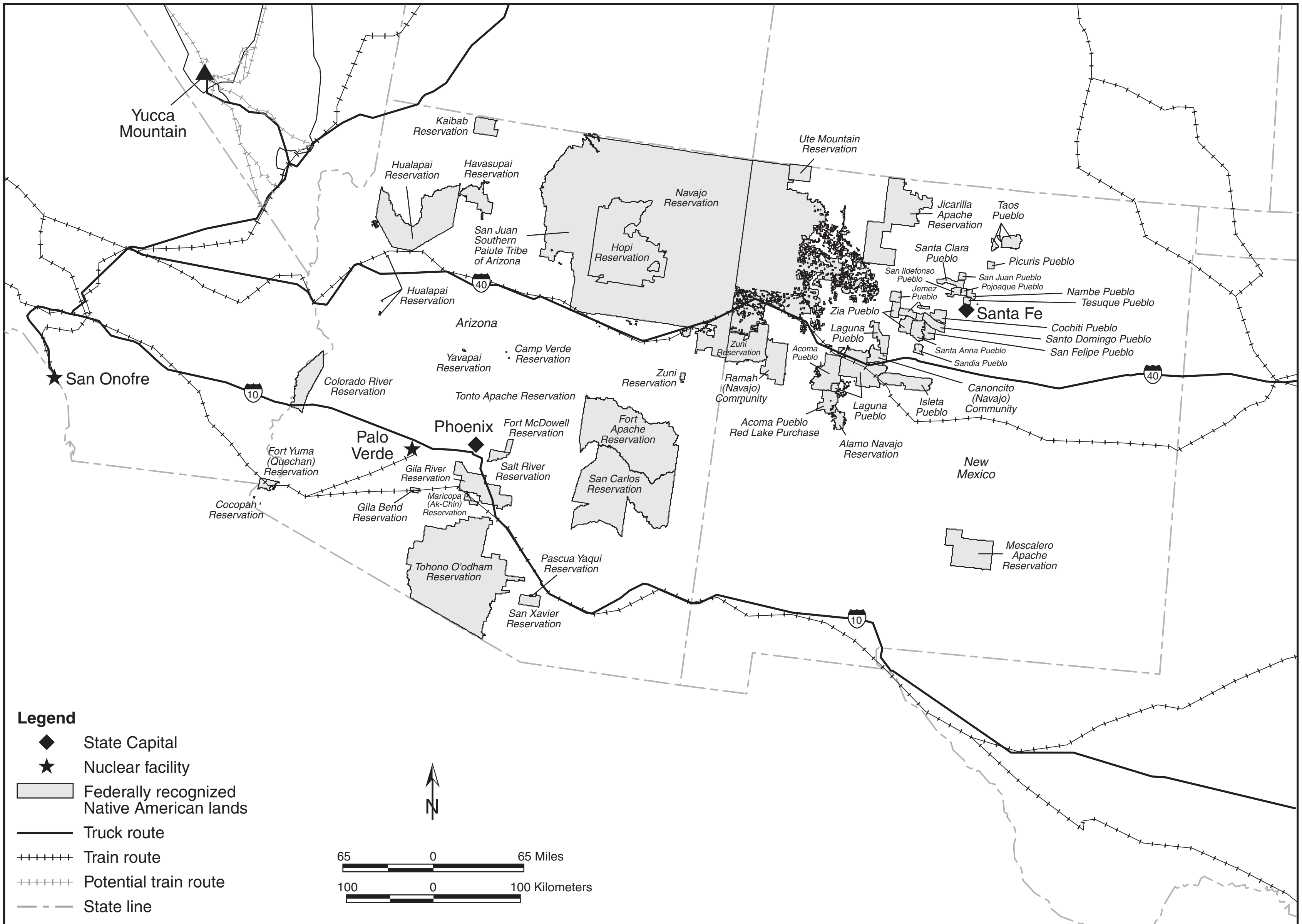
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-33. Highway and rail routes used to analyze transportation impacts - Arizona and New Mexico.

Table J-74. Estimated transportation impacts for the State of California.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
CALIFORNIA							
Shipments							
Truck (originating/total)	1,750/6,867	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	286/660	286/750	286/1,464	286/512	286/594	286/904
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.3\times10^{2}/6.3\times10^{-2}$	$4.8\times10^{1}/2.4\times10^{-2}$	$5.3\times10^{1}/2.6\times10^{-2}$	$6.6\times10^{1}/3.3\times10^{-2}$	$6.9\times10^{1}/3.4\times10^{-2}$	$4.6\times10^{1}/2.3\times10^{-2}$	$5.7\times10^{1}/2.9\times10^{-2}$
Workers (person-rem/LCFs)	$2.7\times10^{2}/1.1\times10^{-1}$	$4.5\times10^{1}/1.8\times10^{-2}$	$5.0\times10^{1}/2.0\times10^{-2}$	$7.7\times10^{1}/3.1\times10^{-2}$	$5.2\times10^{1}/2.1\times10^{-2}$	$4.2\times10^{1}/1.7\times10^{-2}$	$5.7\times10^{1}/2.3\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$9.7\times10^{-3}/4.9\times10^{-6}$	$2.2\times10^{-2}/1.1\times10^{-5}$	$2.5\times10^{-2}/1.3\times10^{-5}$	$3.2\times10^{-2}/1.6\times10^{-5}$	$3.4\times10^{-2}/1.7\times10^{-5}$	$2.1\times10^{-2}/1.1\times10^{-5}$	$2.7\times10^{-2}/1.3\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	4.3×10^{-2}	2.1×10^{-2}	2.3×10^{-2}	3.0×10^{-2}	3.1×10^{-2}	2.0×10^{-2}	2.5×10^{-2}
Fatalities	0.052	0.061	0.073	0.131	0.073	0.055	0.087

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

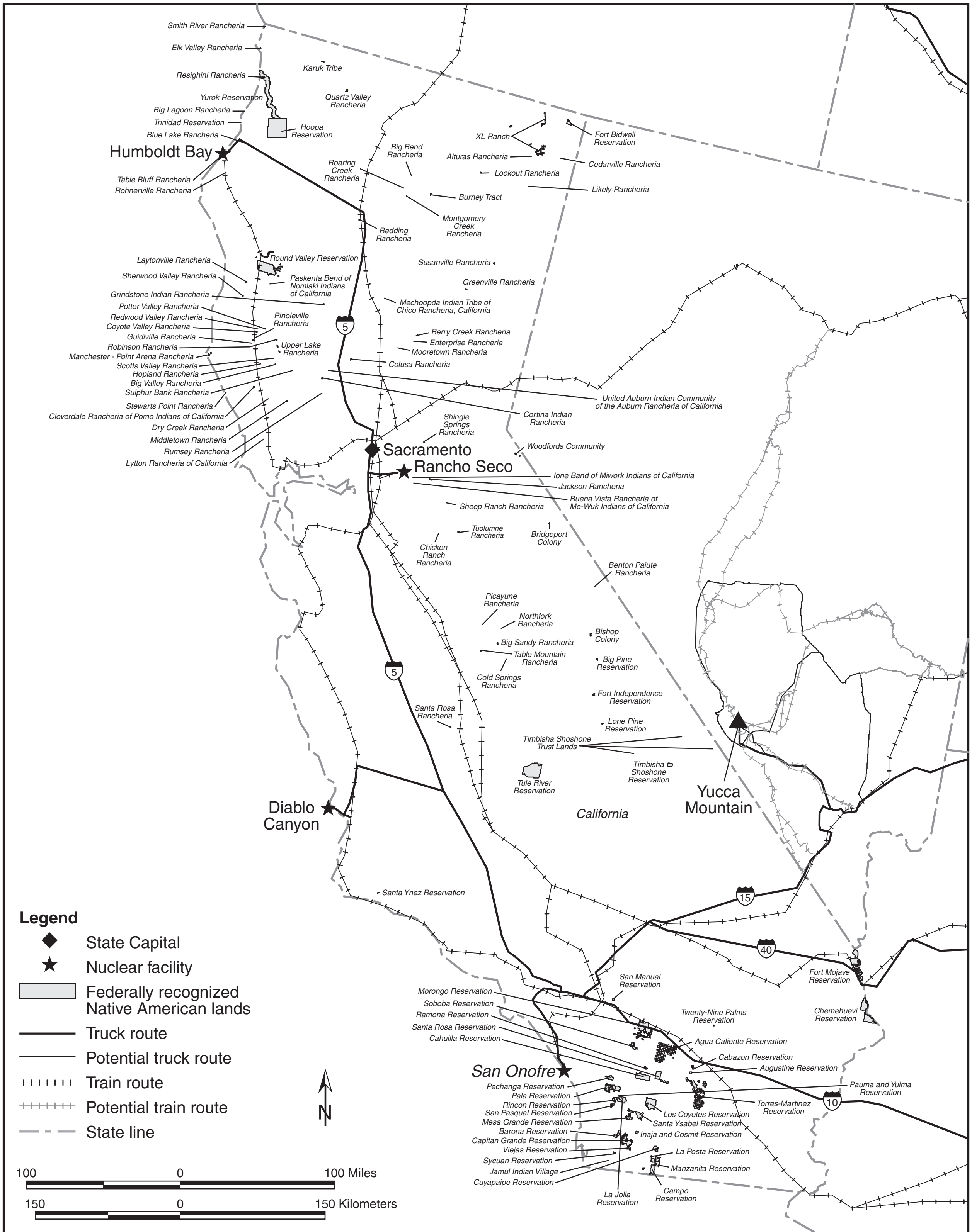
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-34. Highway and rail routes used to analyze transportation impacts - California.

Table J-75. Estimated transportation impacts for the States of Colorado, Kansas, and Nebraska (page 1 of 2).

Impact category	Mostly legal-weight truck	Mostly rail: Ending rail node in Nevada[a] Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
COLORADO							
Shipments							
Truck (originating/total)	312/708	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	36/7,904	36/7,847	36/7,133	36/8,085	36/7,970	36/7,693
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$4.4\times10^{0}/2.2\times10^{-3}$	$1.6\times10^{1}/8.2\times10^{-3}$	$1.4\times10^{1}/7.1\times10^{-3}$	$3.2\times10^{0}/1.6\times10^{-3}$	$2.0\times10^{1}/1.0\times10^{-2}$	$1.9\times10^{1}/9.4\times10^{-3}$	$8.5\times10^{0}/4.3\times10^{-3}$
Workers (person-rem/LCFs)	$1.8\times10^{1}/7.4\times10^{-3}$	$4.0\times10^{1}/1.6\times10^{-2}$	$3.7\times10^{1}/1.5\times10^{-2}$	$1.2\times10^{1}/4.9\times10^{-3}$	$4.7\times10^{1}/1.9\times10^{-2}$	$4.5\times10^{1}/1.8\times10^{-2}$	$2.7\times10^{1}/1.1\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$3.4\times10^{-4}/1.7\times10^{-7}$	$5.2\times10^{-3}/2.6\times10^{-6}$	$4.4\times10^{-3}/2.2\times10^{-6}$	$7.9\times10^{-4}/3.9\times10^{-7}$	$6.6\times10^{-3}/3.3\times10^{-6}$	$6.1\times10^{-3}/3.1\times10^{-6}$	$3.0\times10^{-3}/1.5\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	4.9×10^{-4}	8.0×10^{-3}	6.9×10^{-3}	1.4×10^{-3}	9.9×10^{-3}	9.2×10^{-3}	4.0×10^{-3}
Fatalities	0.005	0.024	0.021	0.007	0.028	0.026	0.015
KANSAS							
Shipments							
Truck (originating/total)	396/396	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	63/4,253	63/4,253	63/4,249	63/4,310	63/4,253	63/4,253
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$6.0\times10^{0}/3.0\times10^{-3}$	$1.7\times10^{1}/8.4\times10^{-3}$	$1.7\times10^{1}/8.4\times10^{-3}$	$1.8\times10^{1}/9.2\times10^{-3}$	$1.7\times10^{1}/8.5\times10^{-3}$	$1.7\times10^{1}/8.4\times10^{-3}$	$1.7\times10^{1}/8.4\times10^{-3}$
Workers (person-rem/LCFs)	$2.6\times10^{1}/1.0\times10^{-2}$	$8.3\times10^{1}/3.3\times10^{-2}$	$8.3\times10^{1}/3.3\times10^{-2}$	$8.6\times10^{1}/3.5\times10^{-2}$	$8.4\times10^{1}/3.4\times10^{-2}$	$8.3\times10^{1}/3.3\times10^{-2}$	$8.3\times10^{1}/3.3\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$2.4\times10^{-4}/1.2\times10^{-7}$	$7.9\times10^{-3}/3.9\times10^{-6}$	$7.9\times10^{-3}/3.9\times10^{-6}$	$8.7\times10^{-3}/4.3\times10^{-6}$	$8.0\times10^{-3}/4.0\times10^{-6}$	$7.9\times10^{-3}/3.9\times10^{-6}$	$7.9\times10^{-3}/3.9\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	4.6×10^{-4}	8.5×10^{-3}	8.5×10^{-3}	9.3×10^{-3}	8.6×10^{-3}	8.5×10^{-3}	8.5×10^{-3}
Fatalities	0.003	0.049	0.049	0.051	0.050	0.049	0.049
NEBRASKA							
Shipments							
Truck (originating/total)	532/40,799	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079
Rail (originating/total)	0/0	103/7,657	103/7,657	103/7,097	103/7,714	103/7,657	103/7,657
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$6.4\times10^{2}/3.2\times10^{-1}$	$6.2\times10^{1}/3.1\times10^{-2}$	$6.2\times10^{1}/3.1\times10^{-2}$	$5.9\times10^{1}/2.9\times10^{-2}$	$6.3\times10^{1}/3.1\times10^{-2}$	$6.2\times10^{1}/3.1\times10^{-2}$	$6.2\times10^{1}/3.1\times10^{-2}$
Workers (person-rem/LCFs)	$2.0\times10^{3}/7.8\times10^{-1}$	$3.9\times10^{2}/1.6\times10^{-1}$	$3.9\times10^{2}/1.6\times10^{-1}$	$3.7\times10^{2}/1.5\times10^{-1}$	$4.0\times10^{2}/1.6\times10^{-1}$	$3.9\times10^{2}/1.6\times10^{-1}$	$3.9\times10^{2}/1.6\times10^{-1}$
Accident dose risk							
Population (person-rem/LCFs)	$3.0\times10^{-2}/1.5\times10^{-5}$	$3.9\times10^{-2}/2.0\times10^{-5}$	$3.9\times10^{-2}/2.0\times10^{-5}$	$3.6\times10^{-2}/1.8\times10^{-5}$	$4.0\times10^{-2}/2.0\times10^{-5}$	$3.9\times10^{-2}/2.0\times10^{-5}$	$3.9\times10^{-2}/2.0\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	5.7×10^{-2}	2.4×10^{-2}	2.4×10^{-2}	2.3×10^{-2}	2.4×10^{-2}	2.4×10^{-2}	2.4×10^{-2}
Fatalities	0.83	0.18	0.18	0.17	0.18	0.18	0.18

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

Table J-75. Estimated transportation impacts for the States of Colorado, Kansas, and Nebraska (page 2 of 2).

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

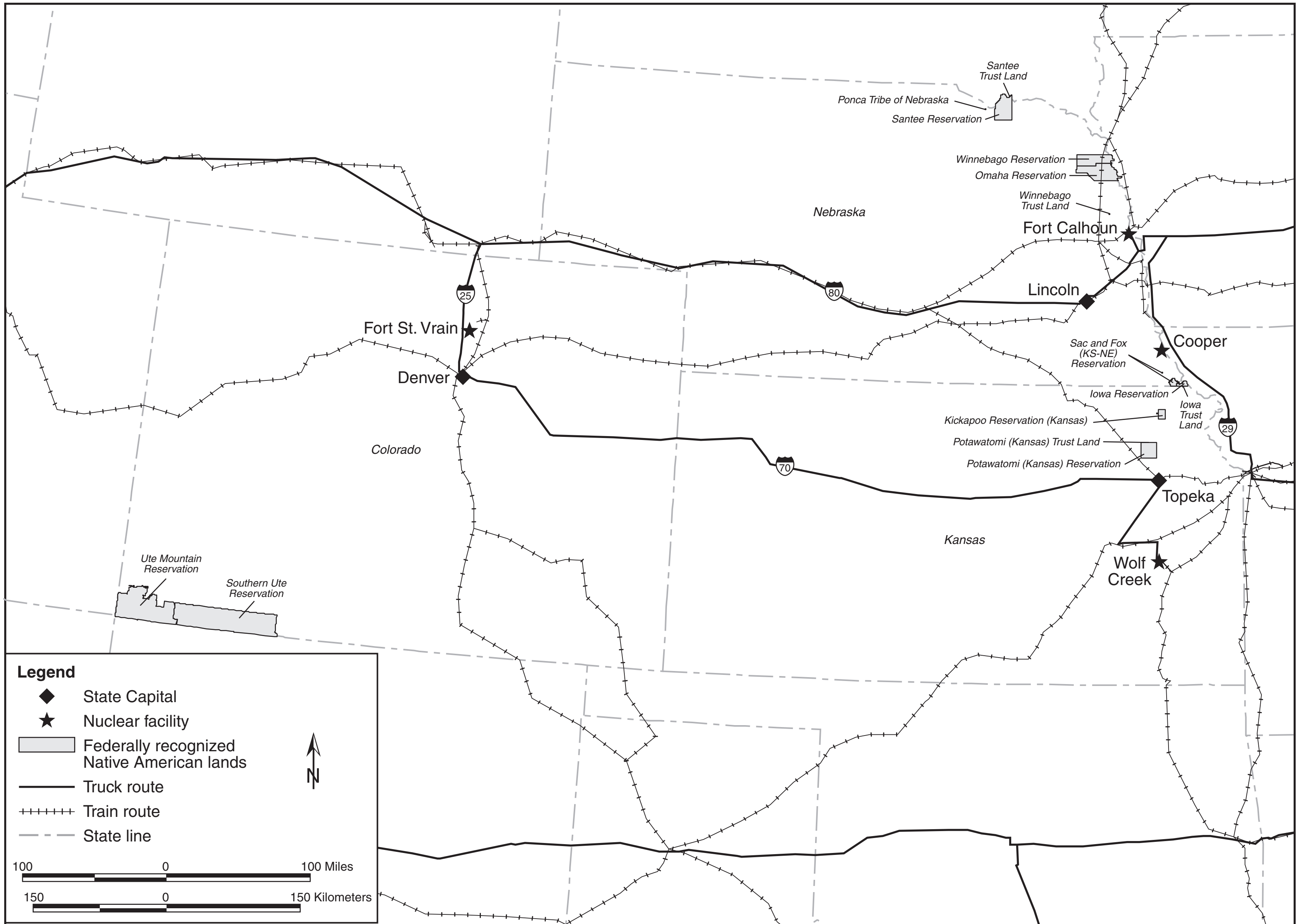
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-35. Highway and rail routes used to analyze transportation impacts - Colorado, Kansas, and Nebraska.

Main Index

Vol 2 Index

Table J-76. Estimated transportation impacts for the States of Connecticut, Rhode Island, and New York (page 1 of 2).

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
CONNECTICUT							
Shipments							
Truck (originating/total)	1,247/1,247	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	295/295	295/295	295/295	295/295	295/295	295/295
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.5\times10^{1}/7.5\times10^{-3}$	$9.1\times10^{0}/4.6\times10^{-3}$	$9.1\times10^{0}/4.6\times10^{-3}$	$9.1\times10^{0}/4.6\times10^{-3}$	$9.1\times10^{0}/4.6\times10^{-3}$	$9.1\times10^{0}/4.6\times10^{-3}$	$9.1\times10^{0}/4.6\times10^{-3}$
Workers (person-rem/LCFs)	$3.4\times10^{1}/1.4\times10^{-2}$	$1.7\times10^{1}/7.0\times10^{-3}$	$1.7\times10^{1}/7.0\times10^{-3}$	$1.7\times10^{1}/7.0\times10^{-3}$	$1.7\times10^{1}/7.0\times10^{-3}$	$1.7\times10^{1}/7.0\times10^{-3}$	$1.7\times10^{1}/7.0\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$8.2\times10^{-3}/4.1\times10^{-6}$	$1.6\times10^{-1}/8.2\times10^{-5}$	$1.6\times10^{-1}/8.2\times10^{-5}$	$.6\times10^{-1}/8.2\times10^{-5}$	$1.6\times10^{-1}/8.2\times10^{-5}$	$1.6\times10^{-1}/8.2\times10^{-5}$	$1.6\times10^{-1}/8.2\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	6.5×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}
Fatalities	0.005	0.135	0.135	0.135	0.135	0.135	0.135
RHODE ISLAND							
Shipments	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Truck (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Radiological impacts	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Incident-free impacts	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Population (person-rem/LCFs)[h]	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Workers (person-rem/LCFs)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Accident dose risk	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Population (person-rem/LCFs)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Nonradiological impacts	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Vehicle emissions (LCFs)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Fatalities	0/0	0/0	0/0	0/0	0/0	0/0	0/0
NEW YORK							
Shipments							
Truck (originating/total)	2,571/5,287	426/580	426/580	426/580	426/580	426/580	426/580
Rail (originating/total)	0/0	350/861	350/861	350/861	350/861	350/861	350/861
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$6.3\times10^{1}/3.2\times10^{-2}$	$3.1\times10^{1}/1.6\times10^{-2}$	$3.1\times10^{1}/1.6\times10^{-2}$	$3.1\times10^{1}/1.6\times10^{-2}$	$3.1\times10^{1}/1.6\times10^{-2}$	$3.1\times10^{1}/1.6\times10^{-2}$	$3.1\times10^{1}/1.6\times10^{-2}$
Workers (person-rem/LCFs)	$1.6\times10^{2}/6.2\times10^{-2}$	$6.7\times10^{1}/2.7\times10^{-2}$	$6.7\times10^{1}/2.7\times10^{-2}$	$6.7\times10^{1}/2.7\times10^{-2}$	$6.7\times10^{1}/2.7\times10^{-2}$	$6.7\times10^{1}/2.7\times10^{-2}$	$6.7\times10^{1}/2.7\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$7.0\times10^{-3}/3.5\times10^{-6}$	$4.9\times10^{-2}/2.4\times10^{-5}$	$4.9\times10^{-2}/2.4\times10^{-5}$	$4.9\times10^{-2}/2.4\times10^{-5}$	$4.9\times10^{-2}/2.4\times10^{-5}$	$4.9\times10^{-2}/2.4\times10^{-5}$	$4.9\times10^{-2}/2.4\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.4×10^{-2}	1.3×10^{-2}	1.3×10^{-2}	1.3×10^{-2}	1.3×10^{-2}	1.3×10^{-2}	1.3×10^{-2}
Fatalities	0.042	0.122	0.122	0.122	0.122	0.122	0.122

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/ Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

Table J-76. Estimated transportation impacts for the States of Connecticut, Rhode Island, and New York (page 2 of 2).

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.

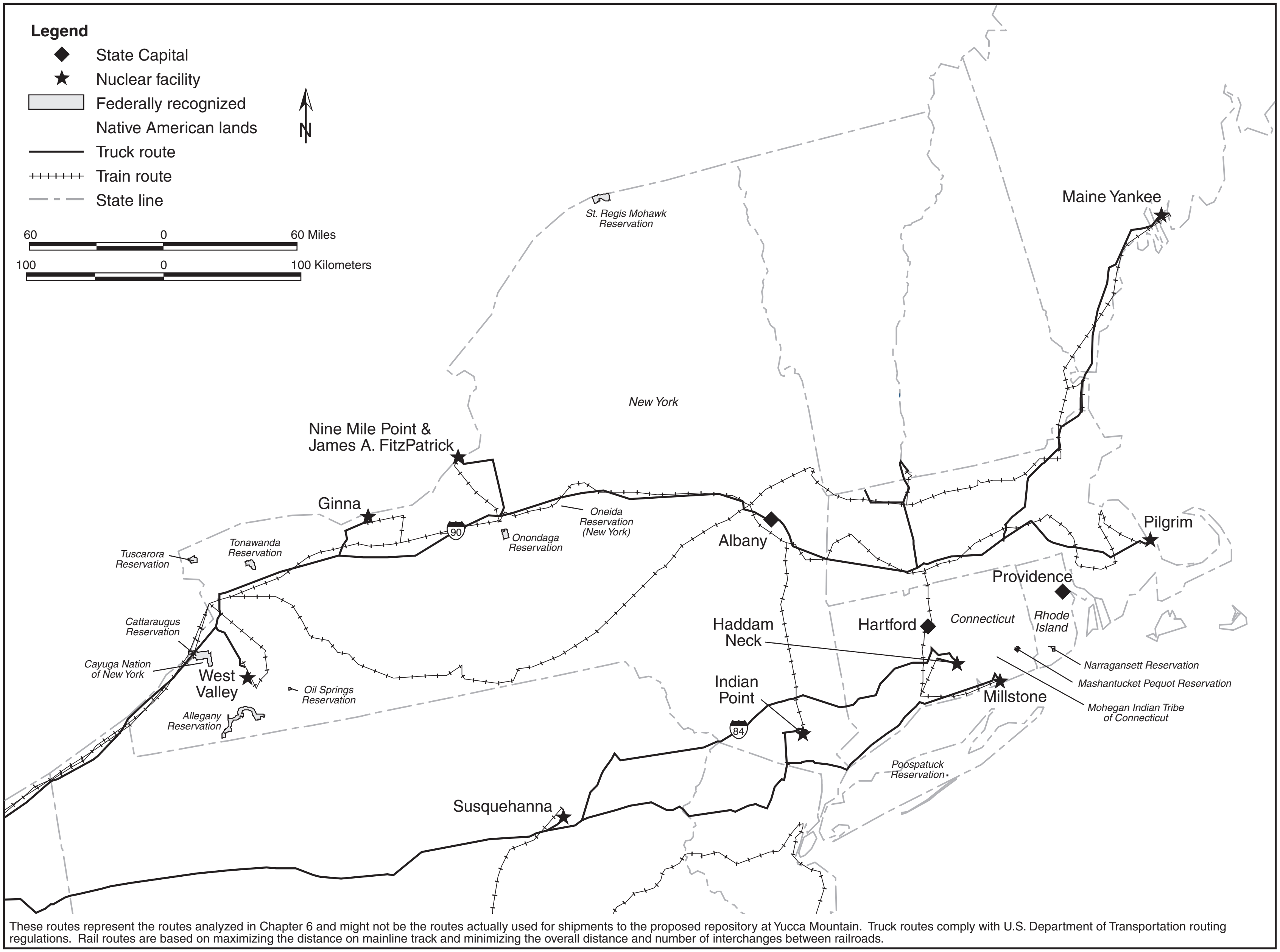


Figure J-36. Highway and rail routes used to analyze transportation impacts - Connecticut, Rhode Island, and New York.

Table J-77. Estimated transportation impacts for the States of Delaware, Maryland, Virginia, West Virginia, and the District of Columbia (page 1 of 3).

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
DELAWARE							
Shipments							
Truck (originating/total)	0/1,077	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.6\times10^{0}/8.2\times10^{-4}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$
Workers (person-rem/LCFs)	$1.7\times10^{0}/6.9\times10^{-4}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$
Accident dose risk							
Population (person-rem/LCFs)	$5.2\times10^{-4}/2.6\times10^{-7}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$	$0.0\times10^{0}/0.0\times10^{0}$
Nonradiological impacts							
Vehicle emissions (LCFs)	6.4×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
Fatalities	3.1×10^{-4}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}	0.0×10^{0}
MARYLAND							
Shipments							
Truck (originating/total)	867/1,944	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	169/312	169/312	169/312	169/312	169/312	169/312
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.5\times10^{1}/1.3\times10^{-2}$	$1.0\times10^{1}/5.0\times10^{-3}$	$1.0\times10^{1}/5.0\times10^{-3}$	$1.0\times10^{1}/5.0\times10^{-3}$	$1.0\times10^{1}/5.0\times10^{-3}$	$1.0\times10^{1}/5.0\times10^{-3}$	$1.0\times10^{1}/5.0\times10^{-3}$
Workers (person-rem/LCFs)	$4.8\times10^{1}/1.9\times10^{-2}$	$1.3\times10^{1}/5.1\times10^{-2}$	$1.3\times10^{1}/5.1\times10^{-2}$	$1.3\times10^{1}/5.1\times10^{-2}$	$1.3\times10^{1}/5.1\times10^{-2}$	$1.3\times10^{1}/5.1\times10^{-2}$	$1.3\times10^{1}/5.1\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$6.6\times10^{-3}/3.3\times10^{-6}$	$3.2\times10^{-3}/1.6\times10^{-6}$	$3.2\times10^{-3}/1.6\times10^{-6}$	$3.2\times10^{-3}/1.6\times10^{-6}$	$3.2\times10^{-3}/1.6\times10^{-6}$	$3.2\times10^{-3}/1.6\times10^{-6}$	$3.2\times10^{-3}/1.6\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	8.4×10^{-3}	3.8×10^{-3}	3.8×10^{-3}	3.8×10^{-3}	3.8×10^{-3}	3.8×10^{-3}	3.8×10^{-3}
Fatalities	0.007	0.007	0.007	0.007	0.007	0.007	0.007

Table J-77. Estimated transportation impacts for the States of Delaware, Maryland, Virginia, West Virginia, and the District of Columbia (page 2 of 3).

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
VIRGINIA							
Shipments							
Truck (originating/total)	1,538/3,409	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	340/340	340/340	340/340	340/340	340/340	340/340
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.2\times10^{1}/1.1\times10^{-2}$	$9.6\times10^{0}/4.8\times10^{-3}$	$9.6\times10^{0}/4.8\times10^{-3}$	$9.6\times10^{0}/4.8\times10^{-3}$	$9.6\times10^{0}/4.8\times10^{-3}$	$9.6\times10^{0}/4.8\times10^{-3}$	$9.6\times10^{0}/4.8\times10^{-3}$
Workers (person-rem/LCFs)	$8.2\times10^{1}/3.3\times10^{-2}$	$2.6\times10^{1}/1.0\times10^{-2}$	$2.6\times10^{1}/1.0\times10^{-2}$	$2.6\times10^{1}/1.0\times10^{-2}$	$2.6\times10^{1}/1.0\times10^{-2}$	$2.6\times10^{1}/1.0\times10^{-2}$	$2.6\times10^{1}/1.0\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$2.1\times10^{-3}/1.1\times10^{-6}$	$2.1\times10^{-3}/1.0\times10^{-6}$	$2.1\times10^{-3}/1.0\times10^{-6}$	$2.1\times10^{-3}/1.0\times10^{-6}$	$2.1\times10^{-3}/1.0\times10^{-6}$	$2.1\times10^{-3}/1.0\times10^{-6}$	$2.1\times10^{-3}/1.0\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	3.4×10^{-3}	2.8×10^{-3}	2.8×10^{-3}	2.8×10^{-3}	2.8×10^{-3}	2.8×10^{-3}	2.8×10^{-3}
Fatalities	0.027	0.011	0.011	0.011	0.011	0.011	0.011
WEST VIRGINIA							
Shipments							
Truck (originating/total)	0/3,409	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/509	0/509	0/509	0/509	0/509	0/509
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$3.4\times10^{1}/1.7\times10^{-2}$	$1.6\times10^{0}/8.1\times10^{-4}$	$1.6\times10^{0}/8.1\times10^{-4}$	$1.6\times10^{0}/8.1\times10^{-4}$	$1.6\times10^{0}/8.1\times10^{-4}$	$1.6\times10^{0}/8.1\times10^{-4}$	$1.6\times10^{0}/8.1\times10^{-4}$
Workers (person-rem/LCFs)	$6.2\times10^{1}/2.5\times10^{-2}$	$6.6\times10^{0}/2.6\times10^{-3}$	$6.6\times10^{0}/2.6\times10^{-3}$	$6.6\times10^{0}/2.6\times10^{-3}$	$6.6\times10^{0}/2.6\times10^{-3}$	$6.6\times10^{0}/2.6\times10^{-3}$	$6.6\times10^{0}/2.6\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$1.8\times10^{-3}/9.2\times10^{-7}$	$3.9\times10^{-4}/2.0\times10^{-7}$	$3.9\times10^{-4}/2.0\times10^{-7}$	$3.9\times10^{-4}/2.0\times10^{-7}$	$3.9\times10^{-4}/2.0\times10^{-7}$	$3.9\times10^{-4}/2.0\times10^{-7}$	$3.9\times10^{-4}/2.0\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	6.9×10^{-3}	8.5×10^{-4}	8.5×10^{-4}	8.5×10^{-4}	8.5×10^{-4}	8.5×10^{-4}	8.5×10^{-4}
Fatalities	0.032	0.004	0.004	0.004	0.004	0.004	0.004

Table J-77. Estimated transportation impacts for the States of Delaware, Maryland, Virginia, West Virginia, and the District of Columbia (page 3 of 3).

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
DISTRICT OF COLUMBIA							
Shipments							
Truck (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/312	0/312	0/312	0/312	0/312	0/312
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$0.0\times10^{0}/0.0\times10^{0}$	$2.7\times10^{0}/1.3\times10^{-3}$	$2.7\times10^{0}/1.3\times10^{-3}$	$2.7\times10^{0}/1.3\times10^{-3}$	$2.7\times10^{0}/1.3\times10^{-3}$	$2.7\times10^{0}/1.3\times10^{-3}$	$2.7\times10^{0}/1.3\times10^{-3}$
Workers (person-rem/LCFs)	$0.0\times10^{0}/0.0\times10^{0}$	$5.9\times10^{-1}/2.4\times10^{-4}$	$5.9\times10^{-1}/2.4\times10^{-4}$	$5.9\times10^{-1}/2.4\times10^{-4}$	$5.9\times10^{-1}/2.4\times10^{-4}$	$5.9\times10^{-1}/2.4\times10^{-4}$	$5.9\times10^{-1}/2.4\times10^{-4}$
Accident dose risk							
Population (person-rem/LCFs)	$0.0\times10^{0}/0.0\times10^{0}$	$5.0\times10^{-2}/2.5\times10^{-5}$	$5.0\times10^{-2}/2.5\times10^{-5}$	$5.0\times10^{-2}/2.5\times10^{-5}$	$5.0\times10^{-2}/2.5\times10^{-5}$	$5.0\times10^{-2}/2.5\times10^{-5}$	$5.0\times10^{-2}/2.5\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	0.0×10^{0}	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}
Fatalities	0.0×10^{0}	4.8×10^{-3}	4.8×10^{-3}	4.8×10^{-3}	4.8×10^{-3}	4.8×10^{-3}	4.8×10^{-3}

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

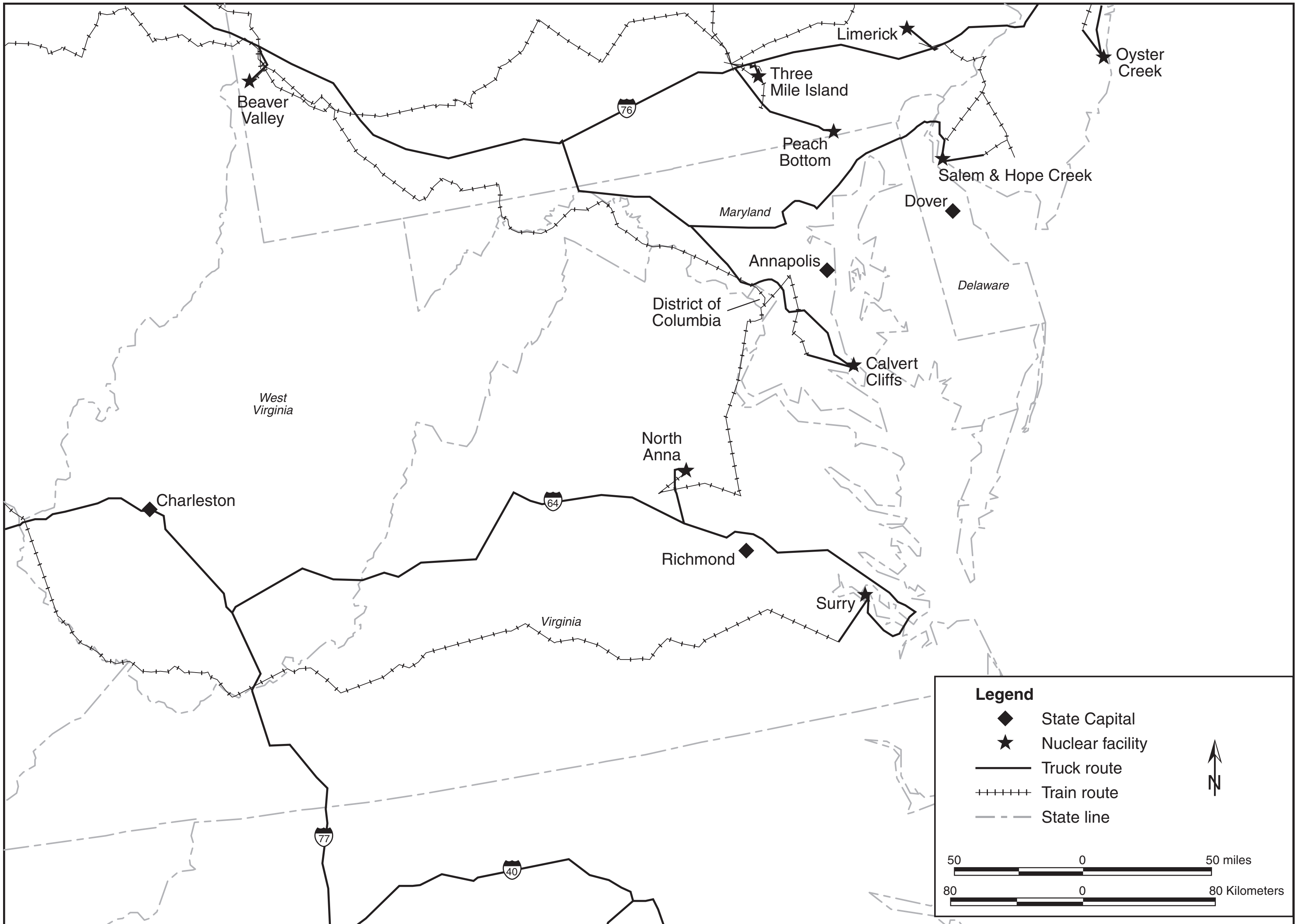
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-37. Highway and rail routes used to analyze transportation impacts - Delaware, Maryland, Virginia, West Virginia, and the District of Columbia.

Main Index

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Table J-78. Estimated transportation impacts for the State of Florida.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
FLORIDA							
Shipments							
Truck (originating/total)	1,666/2,359	491/491	491/491	491/491	491/491	491/491	491/491
Rail (originating/total)	0/0	202/202	202/202	202/202	202/202	202/202	202/202
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$4.5\times10^{1}/2.2\times10^{-2}$	$2.3\times10^{1}/1.2\times10^{-2}$	$2.3\times10^{1}/1.2\times10^{-2}$	$2.8\times10^{1}/1.4\times10^{-2}$	$2.3\times10^{1}/1.2\times10^{-2}$	$2.3\times10^{1}/1.2\times10^{-2}$	$2.3\times10^{1}/1.2\times10^{-2}$
Workers (person-rem/LCFs)	$1.1\times10^{2}/4.3\times10^{-2}$	$4.2\times10^{1}/1.7\times10^{-2}$	$4.2\times10^{1}/1.7\times10^{-2}$	$5.0\times10^{1}/2.0\times10^{-2}$	$4.2\times10^{1}/1.7\times10^{-2}$	$4.2\times10^{1}/1.7\times10^{-2}$	$4.2\times10^{1}/1.7\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$1.5\times10^{-3}/7.4\times10^{-7}$	$7.4\times10^{-3}/3.7\times10^{-6}$	$7.4\times10^{-3}/3.7\times10^{-6}$	$9.9\times10^{-3}/5.0\times10^{-6}$	$7.4\times10^{-3}/3.7\times10^{-6}$	$7.4\times10^{-3}/3.7\times10^{-6}$	$7.4\times10^{-3}/3.7\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.4×10^{-2}	8.2×10^{-3}	8.2×10^{-3}	1.1×10^{-2}	8.2×10^{-3}	8.2×10^{-3}	8.2×10^{-3}
Fatalities	0.019	0.025	0.025	0.047	0.025	0.025	0.025

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

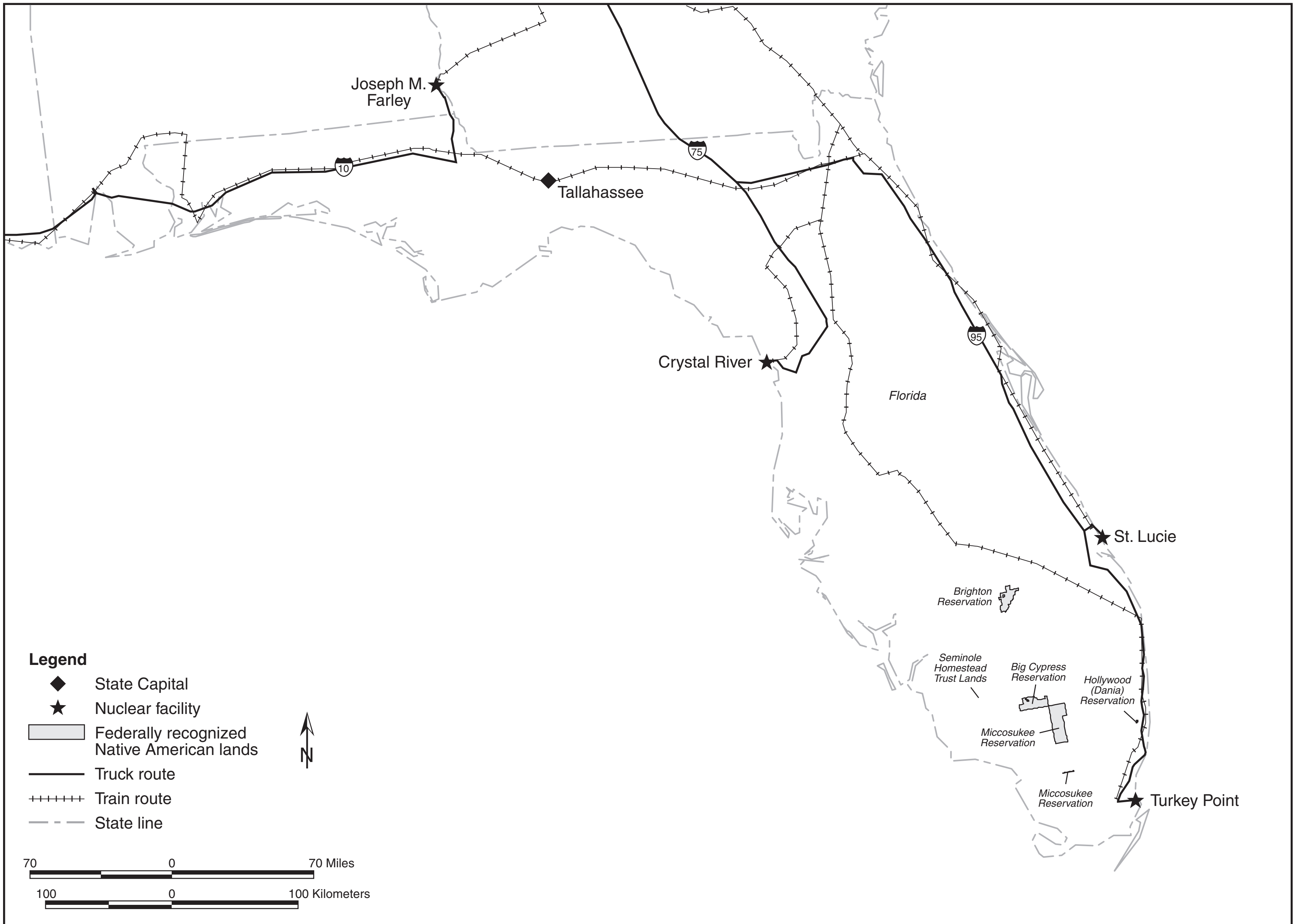
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-38. Highway and rail routes used to analyze transportation impacts - Florida.

Table J-79. Estimated transportation impacts for the State of Iowa.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
IOWA							
Shipments							
Truck (originating/total)	324/40,539	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079
Rail (originating/total)	0/0	57/3,301	57/3,301	57/3,301	57/3,301	57/3,301	57/3,301
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.7\times10^{2}/1.4\times10^{-1}$	$6.2\times10^{1}/3.1\times10^{-2}$	$6.2\times10^{1}/3.1\times10^{-2}$	$6.0\times10^{1}/3.0\times10^{-2}$	$6.2\times10^{1}/3.1\times10^{-2}$	$6.2\times10^{1}/3.1\times10^{-2}$	$6.2\times10^{1}/3.1\times10^{-2}$
Workers (person-rem/LCFs)	$8.7\times10^{2}/3.5\times10^{-1}$	$1.4\times10^{2}/5.7\times10^{-2}$	$1.4\times10^{2}/5.7\times10^{-2}$	$1.3\times10^{2}/5.4\times10^{-2}$	$1.4\times10^{2}/5.7\times10^{-2}$	$1.4\times10^{2}/5.7\times10^{-2}$	$1.4\times10^{2}/5.7\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$4.2\times10^{-3}/2.1\times10^{-6}$	$5.8\times10^{-2}/2.9\times10^{-5}$	$5.8\times10^{-2}/2.9\times10^{-5}$	$5.4\times10^{-2}/2.7\times10^{-5}$	$5.8\times10^{-2}/2.9\times10^{-5}$	$5.8\times10^{-2}/2.9\times10^{-5}$	$5.8\times10^{-2}/2.9\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.4×10^{-2}	2.7×10^{-2}	2.7×10^{-2}	2.6×10^{-2}	2.7×10^{-2}	2.7×10^{-2}	2.7×10^{-2}
Fatalities	0.25	0.09	0.09	0.09	0.09	0.09	0.09

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

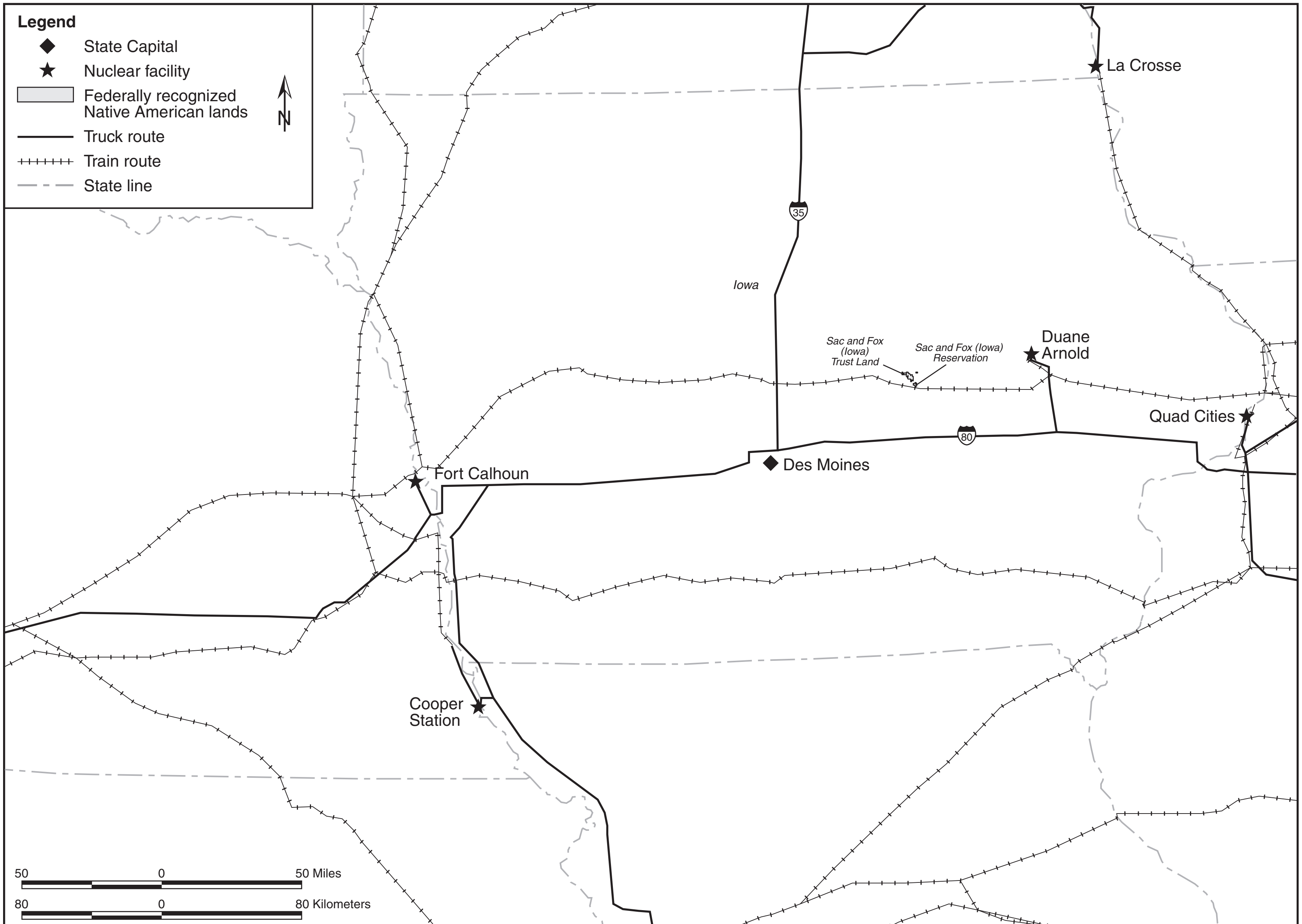
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-39. Highway and rail routes used to analyze transportation impacts - Iowa.

Table J-80. Estimated transportation impacts for the States of Idaho, Oregon, and Washington (page 1 of 2).

		Mostly rail					
		Ending rail node in Nevada[a]					
Impact category	Mostly legal-weight truck	Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
IDAHO							
Shipments							
Truck (originating/total)	1,088/4,412	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	300/300	433/1,082	433/1,049	433/1,049	433/1,049	433/1,082	433/1,049
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$4.2\times10^{1}/2.1\times10^{-2}$	$1.4\times10^{1}/7.0\times10^{-3}$	$1.4\times10^{1}/7.0\times10^{-3}$	$4.8\times10^{1}/2.4\times10^{-2}$	$1.4\times10^{1}/7.0\times10^{-3}$	$1.4\times10^{1}/7.0\times10^{-3}$	$1.4\times10^{1}/7.0\times10^{-3}$
Workers (person-rem/LCFs)	$1.4\times10^{2}/5.5\times10^{-2}$	$4.7\times10^{1}/1.9\times10^{-2}$	$4.7\times10^{1}/1.9\times10^{-2}$	$1.7\times10^{2}/6.8\times10^{-2}$	$4.7\times10^{1}/1.9\times10^{-2}$	$4.7\times10^{1}/1.9\times10^{-2}$	$4.7\times10^{1}/1.9\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$1.7\times10^{-3}/8.7\times10^{-7}$	$7.9\times10^{-4}/4.0\times10^{-7}$	$7.9\times10^{-4}/4.0\times10^{-7}$	$2.4\times10^{-3}/1.2\times10^{-6}$	$7.9\times10^{-4}/4.0\times10^{-7}$	$7.9\times10^{-4}/4.0\times10^{-7}$	$7.9\times10^{-4}/4.0\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	5.2×10^{-3}	4.2×10^{-3}	4.2×10^{-3}	8.0×10^{-3}	4.2×10^{-3}	4.2×10^{-3}	4.2×10^{-3}
Fatalities	0.018	0.039	0.039	0.048	0.039	0.039	0.039
OREGON							
Shipments							
Truck (originating/total)	195/3,324	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	33/649	33/649	33/649	33/649	33/649	33/649
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.3\times10^{1}/1.2\times10^{-2}$	$3.7\times10^{0}/1.8\times10^{-3}$	$4.4\times10^{0}/2.2\times10^{-3}$	$4.4\times10^{0}/2.2\times10^{-3}$	$4.4\times10^{0}/2.2\times10^{-3}$	$3.7\times10^{0}/1.8\times10^{-3}$	$4.4\times10^{0}/2.2\times10^{-3}$
Workers (person-rem/LCFs)	$7.9\times10^{1}/3.2\times10^{-2}$	$1.8\times10^{1}/7.3\times10^{-3}$	$1.8\times10^{1}/7.2\times10^{-3}$	$1.8\times10^{1}/7.2\times10^{-3}$	$1.8\times10^{1}/7.2\times10^{-3}$	$1.8\times10^{1}/7.3\times10^{-3}$	$1.8\times10^{1}/7.2\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$4.4\times10^{-4}/2.2\times10^{-7}$	$1.7\times10^{-3}/8.5\times10^{-7}$	$2.5\times10^{-3}/1.2\times10^{-6}$	$2.5\times10^{-3}/1.2\times10^{-6}$	$2.5\times10^{-3}/1.2\times10^{-6}$	$1.7\times10^{-3}/8.5\times10^{-7}$	$2.5\times10^{-3}/1.2\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.5×10^{-3}	1.7×10^{-3}	2.1×10^{-3}	2.1×10^{-3}	2.1×10^{-3}	1.7×10^{-3}	2.1×10^{-3}
Fatalities	0.048	0.023	0.022	0.022	0.022	0.023	0.022

Table J-80. Estimated transportation impacts for the States of Idaho, Oregon, and Washington (page 2 of 2).

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[d]	Apex[e]
WASHINGTON							
Shipments							
Truck (originating/total)	3,129/3,324	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	616/616	616/616	616/616	616/616	616/616	616/616
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[b]	$9.7\times10^{0}/4.9\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$
Workers (person-rem/LCFs)	$7.6\times10^{1}/3.0\times10^{-2}$	$3.2\times10^{1}/1.3\times10^{-2}$	$3.2\times10^{1}/1.3\times10^{-2}$	$3.2\times10^{1}/1.3\times10^{-2}$	$3.2\times10^{1}/1.3\times10^{-2}$	$3.2\times10^{1}/1.3\times10^{-2}$	$3.2\times10^{1}/1.3\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$8.8\times10^{-4}/4.4\times10^{-7}$	$6.7\times10^{-4}/3.4\times10^{-7}$	$6.7\times10^{-4}/3.4\times10^{-7}$	$6.7\times10^{-4}/3.4\times10^{-7}$	$6.7\times10^{-4}/3.4\times10^{-7}$	$6.7\times10^{-4}/3.4\times10^{-7}$	$6.7\times10^{-4}/3.4\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	2.7×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	2.2×10^{-3}
Fatalities	0.001	0.005	0.005	0.005	0.005	0.005	0.005

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

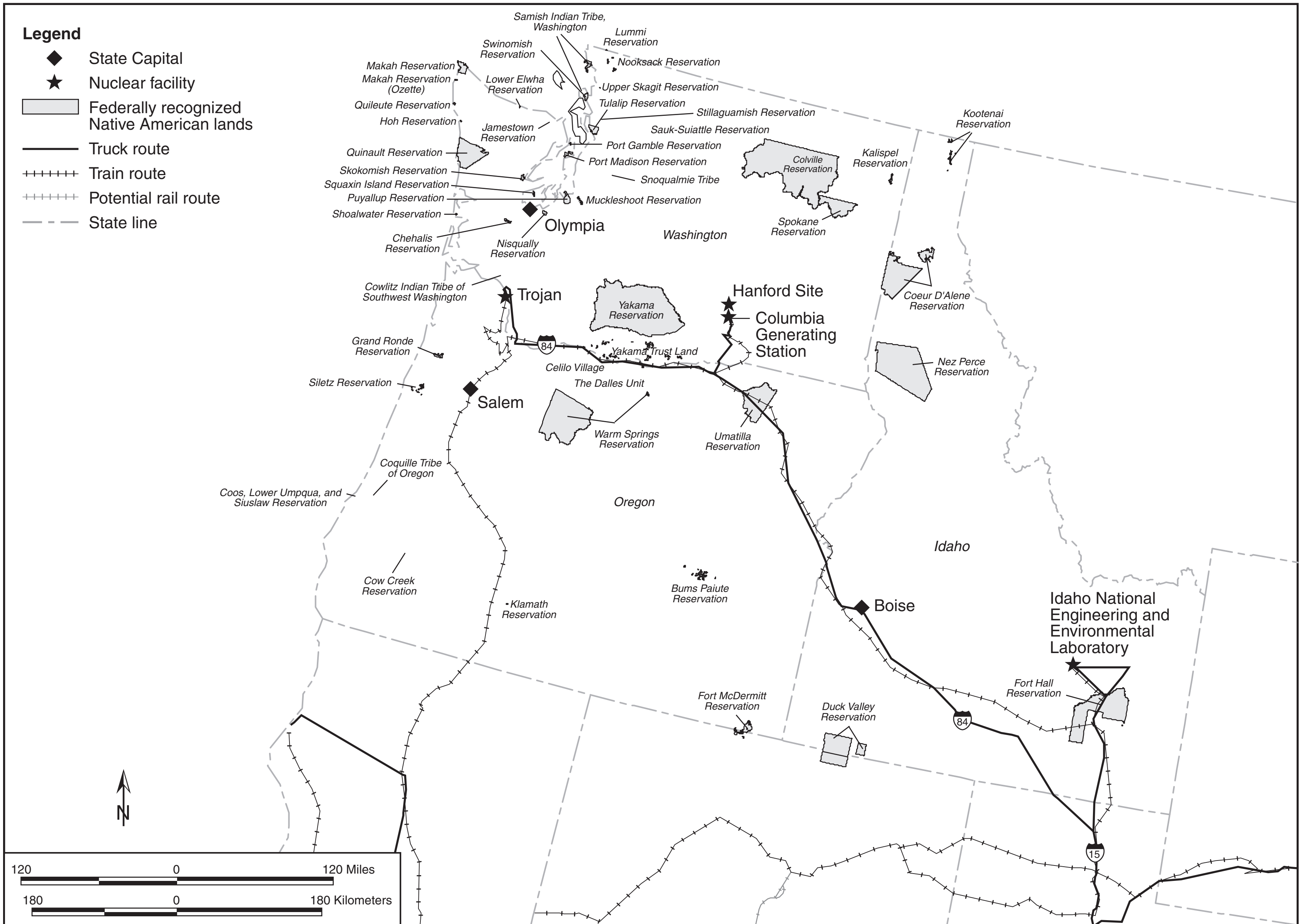
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-40. Highway and rail routes used to analyze transportation impacts - Idaho, Oregon, and Washington.

Main Index

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Table J-81. Estimated transportation impacts for the States of Indiana, Michigan, and Ohio (page 1 of 2).

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[d]	Apex[e]
INDIANA							
Shipments							
Truck (originating/total)	0/17,258	0/580	0/580	0/580	0/580	0/580	0/580
Rail (originating/total)	0/0	0/5,980	0/5,980	0/5,778	0/5,980	0/5,980	0/5,980
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.2\times10^{2}/6.0\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$	$5.4\times10^{1}/2.7\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$
Workers (person-rem/LCFs)	$2.5\times10^{2}/9.9\times10^{-2}$	$8.1\times10^{1}/3.2\times10^{-2}$	$8.1\times10^{1}/3.2\times10^{-2}$	$7.9\times10^{1}/3.2\times10^{-2}$	$8.1\times10^{1}/3.2\times10^{-2}$	$8.1\times10^{1}/3.2\times10^{-2}$	$8.1\times10^{1}/3.2\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$8.8\times10^{-3}/4.4\times10^{-6}$	$2.4\times10^{-2}/1.2\times10^{-5}$	$2.4\times10^{-2}/1.2\times10^{-5}$	$2.3\times10^{-2}/1.2\times10^{-5}$	$2.4\times10^{-2}/1.2\times10^{-5}$	$2.4\times10^{-2}/1.2\times10^{-5}$	$2.4\times10^{-2}/1.2\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	2.5×10^{-2}	2.6×10^{-2}	2.6×10^{-2}	2.6×10^{-2}	2.6×10^{-2}	2.6×10^{-2}	2.6×10^{-2}
Fatalities	0.05	0.12	0.12	0.12	0.12	0.12	0.12
MICHIGAN							
Shipments							
Truck (originating/total)	1,728/1,728	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	287/287	287/287	287/287	287/287	287/287	287/287
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$8.7\times10^{0}/4.3\times10^{-3}$	$4.7\times10^{0}/2.4\times10^{-3}$	$4.7\times10^{0}/2.4\times10^{-3}$	$4.7\times10^{0}/2.4\times10^{-3}$	$4.7\times10^{0}/2.4\times10^{-3}$	$4.7\times10^{0}/2.4\times10^{-3}$	$4.7\times10^{0}/2.4\times10^{-3}$
Workers (person-rem/LCFs)	$4.9\times10^{1}/2.0\times10^{-2}$	$1.7\times10^{1}/6.7\times10^{-3}$	$1.7\times10^{1}/6.7\times10^{-3}$	$1.7\times10^{1}/6.7\times10^{-3}$	$1.7\times10^{1}/6.7\times10^{-3}$	$1.7\times10^{1}/6.7\times10^{-3}$	$1.7\times10^{1}/6.7\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$6.0\times10^{-4}/3.0\times10^{-7}$	$4.9\times10^{-3}/2.4\times10^{-6}$	$4.9\times10^{-3}/2.4\times10^{-6}$	$4.9\times10^{-3}/2.4\times10^{-6}$	$4.9\times10^{-3}/2.4\times10^{-6}$	$4.9\times10^{-3}/2.4\times10^{-6}$	$4.9\times10^{-3}/2.4\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.4×10^{-3}	1.6×10^{-3}	1.6×10^{-3}	1.6×10^{-3}	1.6×10^{-3}	1.6×10^{-3}	1.6×10^{-3}
Fatalities	0.006	0.010	0.010	0.010	0.010	0.010	0.010
OHIO							
Shipments							
Truck (originating/total)	636/12,121	0/580	0/580	0/580	0/580	0/580	0/580
Rail (originating/total)	0/0	106/2,381	106/2,381	106/2,381	106/2,381	106/2,381	106/2,381
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.6\times10^{2}/7.9\times10^{-2}$	$8.5\times10^{1}/4.3\times10^{-2}$	$8.5\times10^{1}/4.3\times10^{-2}$	$8.5\times10^{1}/4.3\times10^{-2}$	$8.5\times10^{1}/4.3\times10^{-2}$	$8.5\times10^{1}/4.3\times10^{-2}$	$8.5\times10^{1}/4.3\times10^{-2}$
Workers (person-rem/LCFs)	$3.2\times10^{2}/1.3\times10^{-1}$	$9.1\times10^{1}/3.6\times10^{-2}$	$9.1\times10^{1}/3.6\times10^{-2}$	$9.1\times10^{1}/3.6\times10^{-2}$	$9.1\times10^{1}/3.6\times10^{-2}$	$9.1\times10^{1}/3.6\times10^{-2}$	$9.1\times10^{1}/3.6\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$7.7\times10^{-3}/3.8\times10^{-6}$	$2.6\times10^{-2}/1.3\times10^{-5}$	$2.6\times10^{-2}/1.3\times10^{-5}$	$2.6\times10^{-2}/1.3\times10^{-5}$	$2.6\times10^{-2}/1.3\times10^{-5}$	$2.6\times10^{-2}/1.3\times10^{-5}$	$2.6\times10^{-2}/1.3\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	3.1×10^{-2}	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}
Fatalities	0.04	0.08	0.08	0.08	0.08	0.08	0.08

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

Table J-81. Estimated transportation impacts for the States of Indiana, Michigan, and Ohio (page 2 of 2).

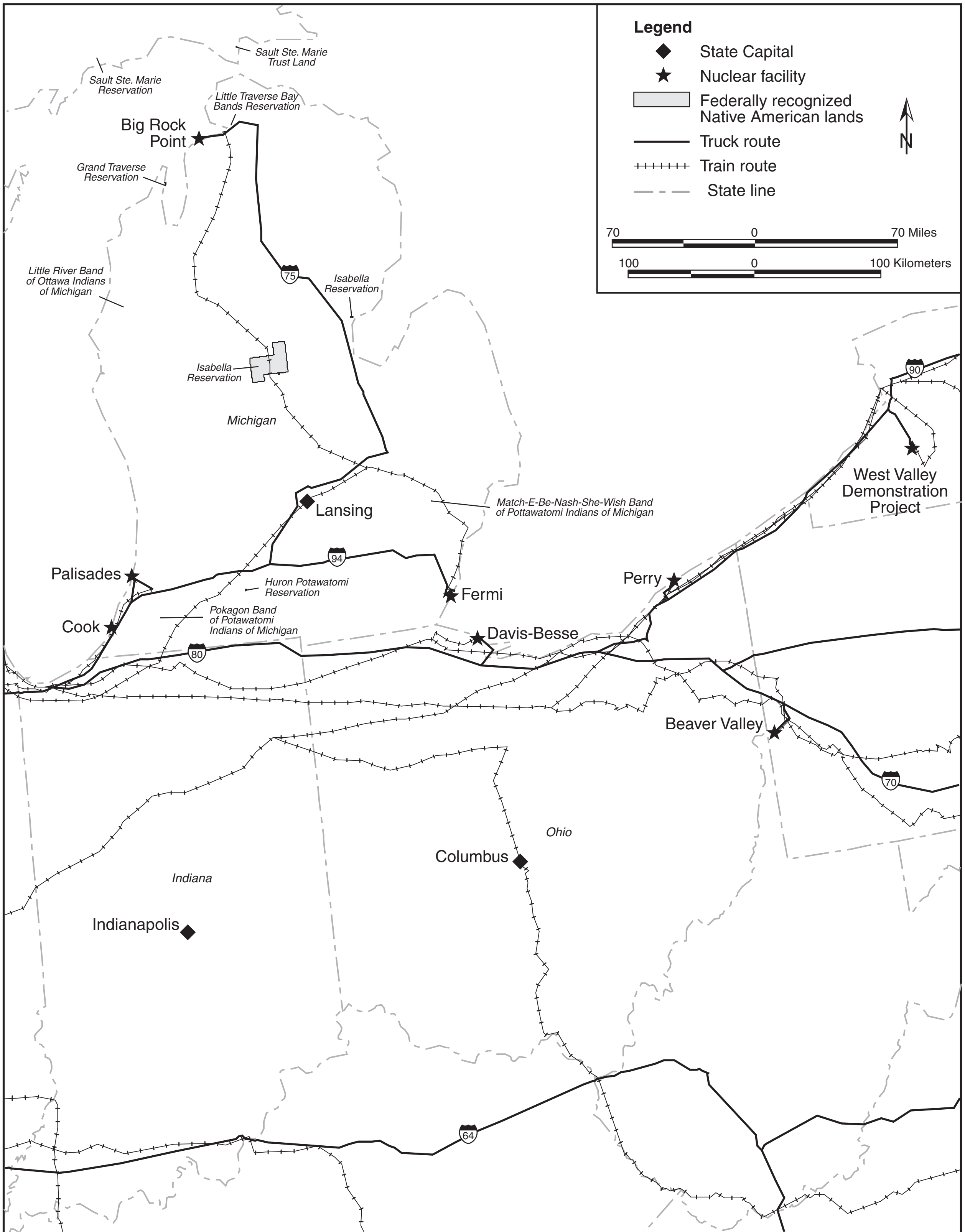
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



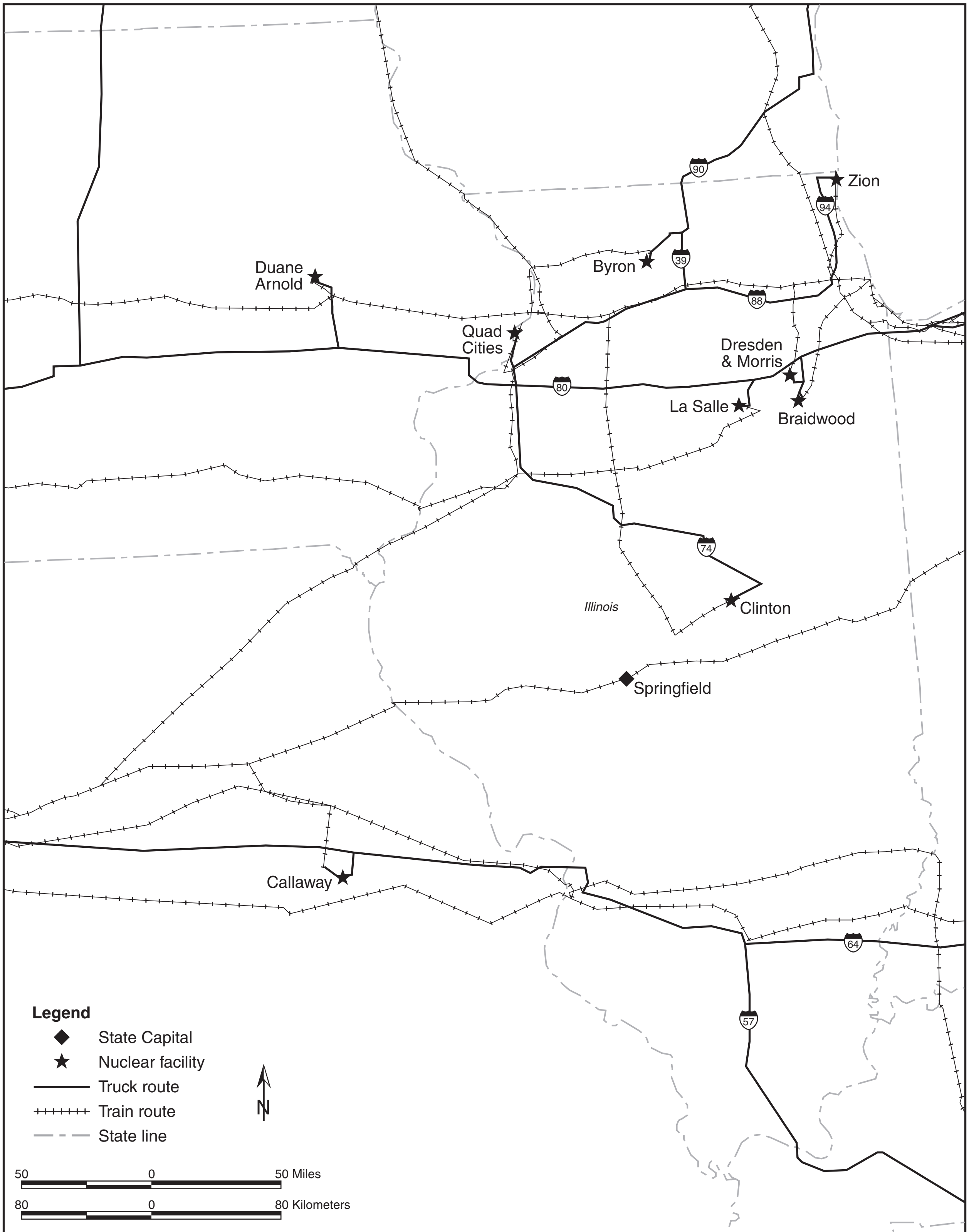
These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-41. Highway and rail routes used to analyze transportation impacts - Indiana, Michigan, and Ohio.

Table J-82. Estimated transportation impacts for the State of Illinois.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
ILLINOIS							
Shipments							
Truck (originating/total)	5,306/38,549	0/1,071	0/1,071	0/1,071	0/1,071	0/1,071	0/1,071
Rail (originating/total)	0/0	861/7,027	861/7,027	861/6,825	861/7,027	861/7,027	861/7,027
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.8\times10^{2}/1.4\times10^{-1}$	$1.8\times10^{2}/8.9\times10^{-2}$	$1.8\times10^{2}/8.9\times10^{-2}$	$1.8\times10^{2}/7.4\times10^{-2}$	$1.8\times10^{2}/8.9\times10^{-2}$	$1.8\times10^{2}/8.9\times10^{-2}$	$1.8\times10^{2}/8.9\times10^{-2}$
Workers (person-rem/LCFs)	$7.6\times10^{2}/3.1\times10^{-1}$	$1.9\times10^{2}/7.5\times10^{-2}$	$1.9\times10^{2}/7.5\times10^{-2}$	$1.8\times10^{2}/7.4\times10^{-2}$	$1.9\times10^{2}/7.5\times10^{-2}$	$1.9\times10^{2}/7.5\times10^{-2}$	$1.9\times10^{2}/7.5\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$1.6\times10^{-2}/8.1\times10^{-6}$	$1.6\times10^{-1}/7.9\times10^{-5}$	$1.6\times10^{-1}/7.9\times10^{-5}$	$1.5\times10^{-1}/7.7\times10^{-5}$	$1.6\times10^{-1}/7.9\times10^{-5}$	$1.6\times10^{-1}/7.9\times10^{-5}$	$1.6\times10^{-1}/7.9\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	4.5×10^{-2}	8.0×10^{-2}	8.0×10^{-2}	7.9×10^{-2}	8.0×10^{-2}	8.0×10^{-2}	8.0×10^{-2}
Fatalities	0.17	0.19	0.19	0.18	0.19	0.19	0.19

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).
b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.
c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.
e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.
f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.
g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.
h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-42. Highway and rail routes used to analyze transportation impacts - Illinois.

Table J-83. Estimated transportation impacts for the States of Kentucky and Tennessee.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
KENTUCKY							
Shipments							
Truck (originating/total)	0/18,435	0/491	0/491	0/491	0/491	0/491	0/491
Rail (originating/total)	0/0	0/3,312	0/3,312	0/3,110	0/3,312	0/3,312	0/3,312
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$8.3\times10^{1}/4.2\times10^{-2}$	$2.0\times10^{1}/1.0\times10^{-2}$	$2.0\times10^{1}/1.0\times10^{-2}$	$1.9\times10^{1}/9.6\times10^{-3}$	$2.0\times10^{1}/1.0\times10^{-2}$	$2.0\times10^{1}/1.0\times10^{-2}$	$2.0\times10^{1}/1.0\times10^{-2}$
Workers (person-rem/LCFs)	$2.2\times10^{2}/8.7\times10^{-2}$	$4.9\times10^{1}/1.9\times10^{-2}$	$4.9\times10^{1}/1.9\times10^{-2}$	$4.7\times10^{1}/1.9\times10^{-2}$	$4.9\times10^{1}/1.9\times10^{-2}$	$4.9\times10^{1}/1.9\times10^{-2}$	$4.9\times10^{1}/1.9\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$5.2\times10^{-3}/2.6\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$3.9\times10^{-3}/2.0\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$3.9\times10^{-3}/2.0\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.1×10^{-2}	9.7×10^{-3}	9.7×10^{-3}	9.3×10^{-3}	9.7×10^{-3}	9.7×10^{-3}	9.7×10^{-3}
Fatalities	0.086	0.041	0.041	0.039	0.041	0.041	0.041
TENNESSEE							
Shipments							
Truck (originating/total)	802/15,026	0/491	0/491	0/491	0/491	0/491	0/491
Rail (originating/total)	0/0	121/3,312	121/3,312	121/3,110	121/3,312	121/3,312	121/3,312
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.4\times10^{2}/6.9\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$	$5.1\times10^{1}/2.5\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$	$5.5\times10^{1}/2.7\times10^{-2}$
Workers (person-rem/LCFs)	$3.1\times10^{2}/1.2\times10^{-1}$	$8.2\times10^{1}/3.3\times10^{-2}$	$8.2\times10^{1}/3.3\times10^{-2}$	$7.7\times10^{1}/3.1\times10^{-2}$	$8.2\times10^{1}/3.3\times10^{-2}$	$8.2\times10^{1}/3.3\times10^{-2}$	$8.2\times10^{1}/3.3\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$4.7\times10^{-3}/2.4\times10^{-6}$	$1.1\times10^{-2}/5.5\times10^{-6}$	$1.1\times10^{-2}/5.5\times10^{-6}$	$9.0\times10^{-3}/4.5\times10^{-6}$	$1.1\times10^{-2}/5.5\times10^{-6}$	$1.1\times10^{-2}/5.5\times10^{-6}$	$1.1\times10^{-2}/5.5\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	2.8×10^{-2}	2.7×10^{-2}	2.7×10^{-2}	2.5×10^{2}	2.7×10^{-2}	2.7×10^{-2}	2.7×10^{-2}
Fatalities	0.09	0.07	0.07	0.07	0.07	0.07	0.07

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

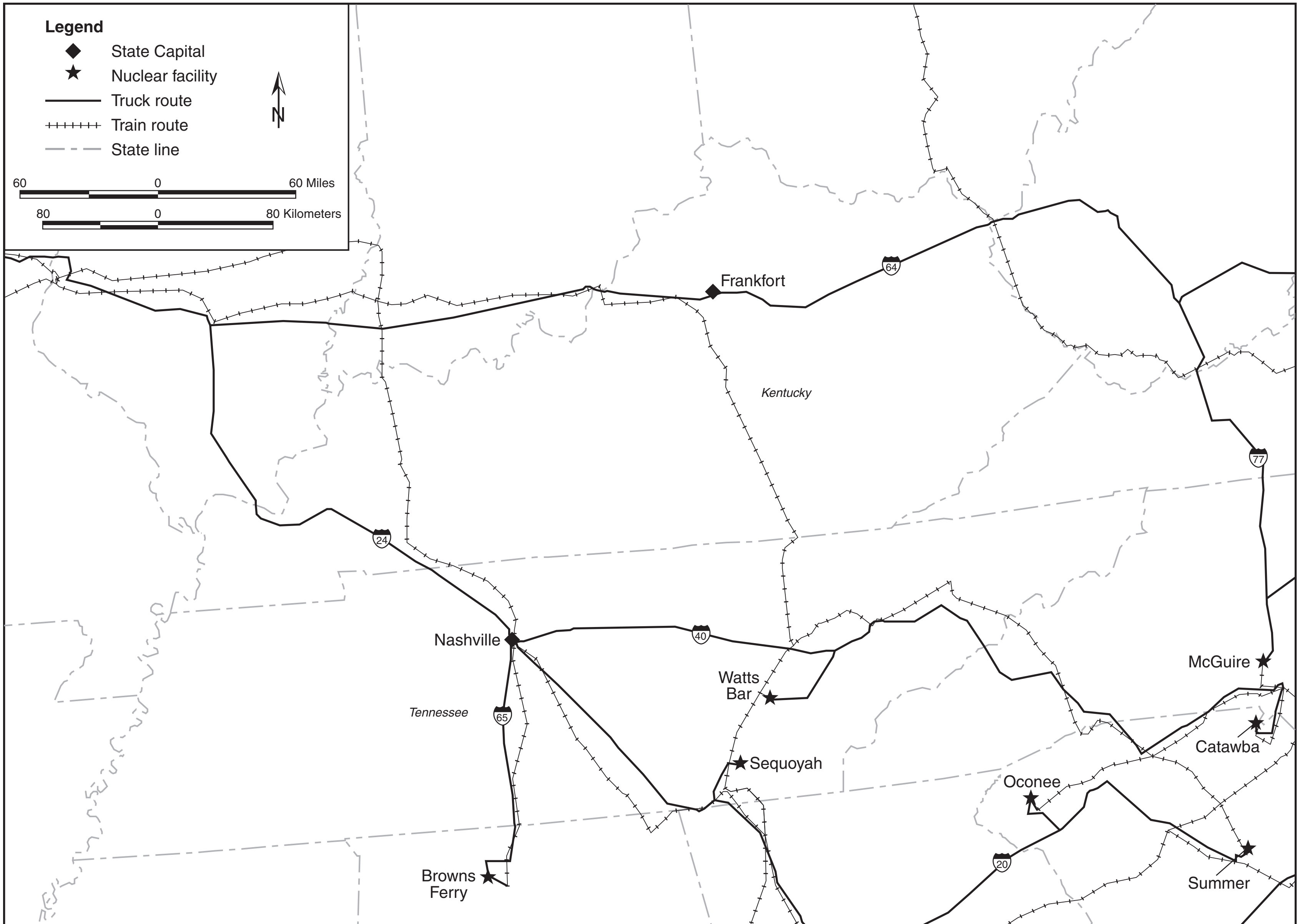
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-43. Highway and rail routes used to analyze transportation impacts - Kentucky and Tennessee.

Table J-84. Estimated transportation impacts for the States of Louisiana and Mississippi.

Impact category	Mostly legal-weight truck	Mostly rail: Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[d]	Apex[e]
LOUISIANA							
Shipments							
Truck (originating/total)	727/2,012	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	123/203	123/203	123/405	123/203	123/203	123/203
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.6\times10^{1}/1.3\times10^{-2}$	$2.9\times10^{0}/1.5\times10^{-3}$	$2.6\times10^{0}/1.3\times10^{-3}$	$7.5\times10^{0}/3.8\times10^{-3}$	$3.0\times10^{0}/1.5\times10^{-3}$	$2.9\times10^{0}/1.5\times10^{-3}$	$2.6\times10^{0}/1.3\times10^{-3}$
Workers (person-rem/LCFs)	$7.7\times10^{1}/3.1\times10^{-2}$	$1.1\times10^{1}/4.3\times10^{-3}$	$1.0\times10^{1}/4.1\times10^{-3}$	$1.7\times10^{1}/6.7\times10^{-3}$	$1.1\times10^{1}/4.4\times10^{-3}$	$1.1\times10^{1}/4.3\times10^{-3}$	$1.0\times10^{1}/4.1\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$1.3\times10^{-3}/6.6\times10^{-7}$	$2.9\times10^{-3}/1.5\times10^{-6}$	$2.5\times10^{-3}/1.3\times10^{-6}$	$9.3\times10^{-3}/4.6\times10^{-6}$	$3.0\times10^{-3}/1.5\times10^{-6}$	$2.9\times10^{-3}/1.5\times10^{-6}$	$2.5\times10^{-3}/1.3\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	3.91×10^{-3}	1.06×10^{-3}	8.98×10^{-4}	3.31×10^{-3}	1.08×10^{-3}	1.06×10^{-3}	8.98×10^{-4}
Fatalities	0.018	0.018	0.016	0.037	0.018	0.018	0.016
MISSISSIPPI							
Shipments							
Truck (originating/total)	592/1,285	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	80/80	80/80	80/282	80/80	80/80	80/80
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.8\times10^{0}/1.4\times10^{-3}$	$6.2\times10^{-1}/3.1\times10^{-4}$	$6.2\times10^{-1}/3.1\times10^{-4}$	$2.7\times10^{0}/1.3\times10^{-3}$	$6.2\times10^{-1}/3.1\times10^{-4}$	$6.2\times10^{-1}/3.1\times10^{-4}$	$6.2\times10^{-1}/3.1\times10^{-4}$
Workers (person-rem/LCFs)	$1.8\times10^{1}/7.3\times10^{-3}$	$4.3\times10^{0}/1.7\times10^{-3}$	$4.3\times10^{0}/1.7\times10^{-3}$	$6.1\times10^{1}/2.4\times10^{-3}$	$4.3\times10^{0}/1.7\times10^{-3}$	$4.3\times10^{0}/1.7\times10^{-3}$	$4.3\times10^{0}/1.7\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$2.3\times10^{-5}/1.1\times10^{-8}$	$1.1\times10^{-5}/5.7\times10^{-9}$	$1.1\times10^{-5}/5.7\times10^{-9}$	$3.3\times10^{-3}/1.7\times10^{-6}$	$1.1\times10^{-5}/5.7\times10^{-9}$	$1.1\times10^{-5}/5.7\times10^{-9}$	$1.1\times10^{-5}/5.7\times10^{-9}$
Nonradiological impacts							
Vehicle emissions (LCFs)	2.7×10^{-4}	8.5×10^{-6}	8.5×10^{-6}	1.1×10^{-3}	8.5×10^{-6}	8.5×10^{-6}	8.5×10^{-6}
Fatalities	5.9×10^{-4}	3.7×10^{-4}	3.7×10^{-4}	4.3×10^{-3}	3.7×10^{-4}	3.7×10^{-4}	3.7×10^{-4}

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

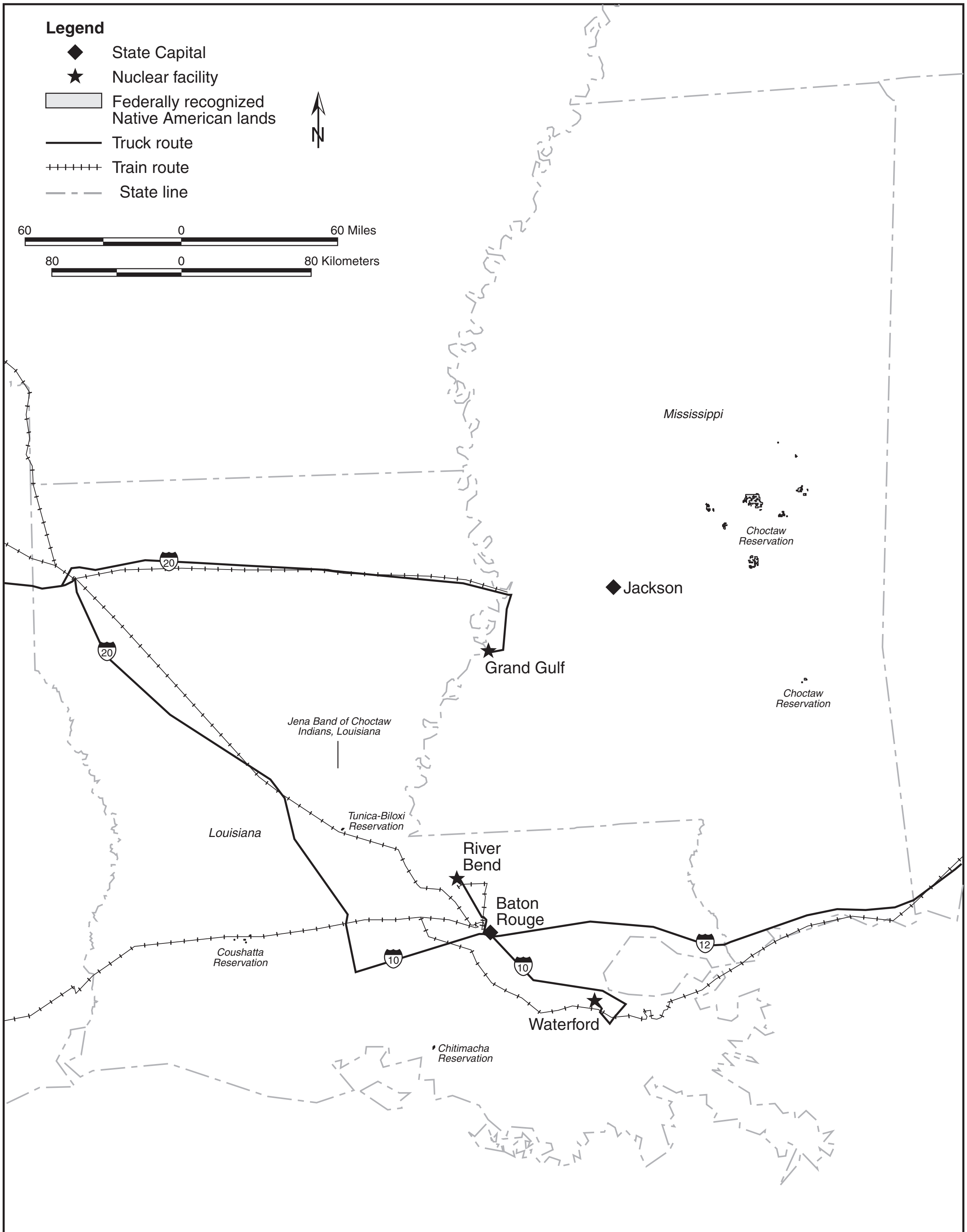
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-44. Highway and rail routes used to analyze transportation impacts - Louisiana and Mississippi.

Table J-85. Estimated transportation impacts for the States of Maine, Massachusetts, New Hampshire, and Vermont (page 1 of 2).

Impact category	Mostly legal-weight truck	Mostly rail: Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
MAINE							
Shipments							
Truck (originating/total)	356/356	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	55/55	55/55	55/55	55/55	55/55	55/55
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.9\times10^{0}/9.5\times10^{-4}$	$5.2\times10^{-1}/2.6\times10^{-4}$	$5.2\times10^{-1}/2.6\times10^{-4}$	$5.2\times10^{-1}/2.6\times10^{-4}$	$5.2\times10^{-1}/2.6\times10^{-4}$	$5.2\times10^{-1}/2.6\times10^{-4}$	$5.2\times10^{-1}/2.6\times10^{-4}$
Workers (person-rem/LCFs)	$9.9\times10^{0}/4.0\times10^{-3}$	$3.2\times10^{0}/1.3\times10^{-3}$	$3.2\times10^{0}/1.3\times10^{-3}$	$3.2\times10^{0}/1.3\times10^{-3}$	$3.2\times10^{0}/1.3\times10^{-3}$	$3.2\times10^{0}/1.3\times10^{-3}$	$3.2\times10^{0}/1.3\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$2.2\times10^{-4}/1.1\times10^{-7}$	$1.1\times10^{-3}/5.6\times10^{-7}$	$1.1\times10^{-3}/5.6\times10^{-7}$	$1.1\times10^{-3}/5.6\times10^{-7}$	$1.1\times10^{-3}/5.6\times10^{-7}$	$1.1\times10^{-3}/5.6\times10^{-7}$	$1.1\times10^{-3}/5.6\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	2.9×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}
Fatalities	9.7×10^{-4}	2.9×10^{-3}	2.9×10^{-3}	2.9×10^{-3}	2.9×10^{-3}	2.9×10^{-3}	2.9×10^{-3}
MASSACHUSETTS							
Shipments							
Truck (originating/total)	456/1,469	154/154	154/154	154/154	154/154	154/154	154/154
Rail (originating/total)	0/0	39/511	39/511	39/511	39/511	39/511	39/511
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.5\times10^{1}/7.3\times10^{-3}$	$7.9\times10^{0}/4.0\times10^{-3}$	$7.9\times10^{0}/4.0\times10^{-3}$	$7.9\times10^{0}/4.0\times10^{-3}$	$7.9\times10^{0}/4.0\times10^{-3}$	$7.9\times10^{0}/4.0\times10^{-3}$	$7.9\times10^{0}/4.0\times10^{-3}$
Workers (person-rem/LCFs)	$3.0\times10^{1}/1.2\times10^{-2}$	$1.3\times10^{1}/1.5\times10^{-3}$	$1.3\times10^{1}/1.5\times10^{-3}$	$1.3\times10^{1}/1.5\times10^{-3}$	$1.3\times10^{1}/1.5\times10^{-3}$	$1.3\times10^{1}/1.5\times10^{-3}$	$1.3\times10^{1}/1.5\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$4.8\times10^{-4}/2.4\times10^{-7}$	$1.5\times10^{-2}/7.3\times10^{-6}$	$1.5\times10^{-2}/7.3\times10^{-6}$	$1.5\times10^{-2}/7.3\times10^{-6}$	$1.5\times10^{-2}/7.3\times10^{-6}$	$1.5\times10^{-2}/7.3\times10^{-6}$	$1.5\times10^{-2}/7.3\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	3.7×10^{-3}	3.3×10^{-3}	3.3×10^{-3}	3.3×10^{-3}	3.3×10^{-3}	3.3×10^{-3}	3.3×10^{-3}
Fatalities	0.001	0.068	0.068	0.068	0.068	0.068	0.068
NEW HAMPSHIRE							
Shipments							
Truck (originating/total)	277/633	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	49/104	49/104	49/104	49/104	49/104	49/104
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[b]	$4.9\times10^{-1}/2.5\times10^{-4}$	$4.4\times10^{-1}/2.2\times10^{-4}$	$4.4\times10^{-1}/2.2\times10^{-4}$	$4.4\times10^{-1}/2.2\times10^{-4}$	$4.4\times10^{-1}/2.2\times10^{-4}$	$4.4\times10^{-1}/2.2\times10^{-4}$	$4.4\times10^{-1}/2.2\times10^{-4}$
Workers (person-rem/LCFs)	$5.7\times10^{0}/2.3\times10^{-3}$	$2.7\times10^{0}/1.1\times10^{-3}$	$2.7\times10^{0}/1.1\times10^{-3}$	$2.7\times10^{0}/1.1\times10^{-3}$	$2.7\times10^{0}/1.1\times10^{-3}$	$2.7\times10^{0}/1.1\times10^{-3}$	$2.7\times10^{0}/1.1\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$4.2\times10^{-5}/2.1\times10^{-8}$	$8.5\times10^{-4}/4.3\times10^{-7}$	$8.5\times10^{-4}/4.3\times10^{-7}$	$8.5\times10^{-4}/4.3\times10^{-7}$	$8.5\times10^{-4}/4.3\times10^{-7}$	$8.5\times10^{-4}/4.3\times10^{-7}$	$8.5\times10^{-4}/4.3\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	8.9×10^{-5}	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}
Fatalities	1.2×10^{-4}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}

Table J-85. Estimated transportation impacts for the States of Maine, Massachusetts, New Hampshire, and Vermont (page 2 of 2).

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
VERMONT							
Shipments							
Truck (originating/total)	380/380	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	73/192	73/192	73/192	73/192	73/192	73/192
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$4.1\times10^{-1}/2.1\times10^{-4}$	$1.6\times10^{-1}/7.8\times10^{-5}$	$1.6\times10^{-1}/7.8\times10^{-5}$	$1.6\times10^{-1}/7.8\times10^{-5}$	$1.6\times10^{-1}/7.8\times10^{-5}$	$1.6\times10^{-1}/7.8\times10^{-5}$	$1.6\times10^{-1}/7.8\times10^{-5}$
Workers (person-rem/LCFs)	$7.5\times10^{0}/3.0\times10^{-3}$	$3.6\times10^{0}/1.4\times10^{-3}$	$3.6\times10^{0}/1.4\times10^{-3}$	$3.6\times10^{0}/1.4\times10^{-3}$	$3.6\times10^{0}/1.4\times10^{-3}$	$3.6\times10^{0}/1.4\times10^{-3}$	$3.6\times10^{0}/1.4\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$2.4\times10^{-5}/1.2\times10^{-8}$	$7.0\times10^{-5}/3.5\times10^{-8}$	$7.0\times10^{-5}/3.5\times10^{-8}$	$7.0\times10^{-5}/3.5\times10^{-8}$	$7.0\times10^{-5}/3.5\times10^{-8}$	$7.0\times10^{-5}/3.5\times10^{-8}$	$7.0\times10^{-5}/3.5\times10^{-8}$
Nonradiological impacts							
Vehicle emissions (LCFs)	8.9×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}
Fatalities	1.1×10^{-4}	1.5×10^{-4}	1.5×10^{-4}	1.5×10^{-4}	1.5×10^{-4}	1.5×10^{-4}	1.5×10^{-4}

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.

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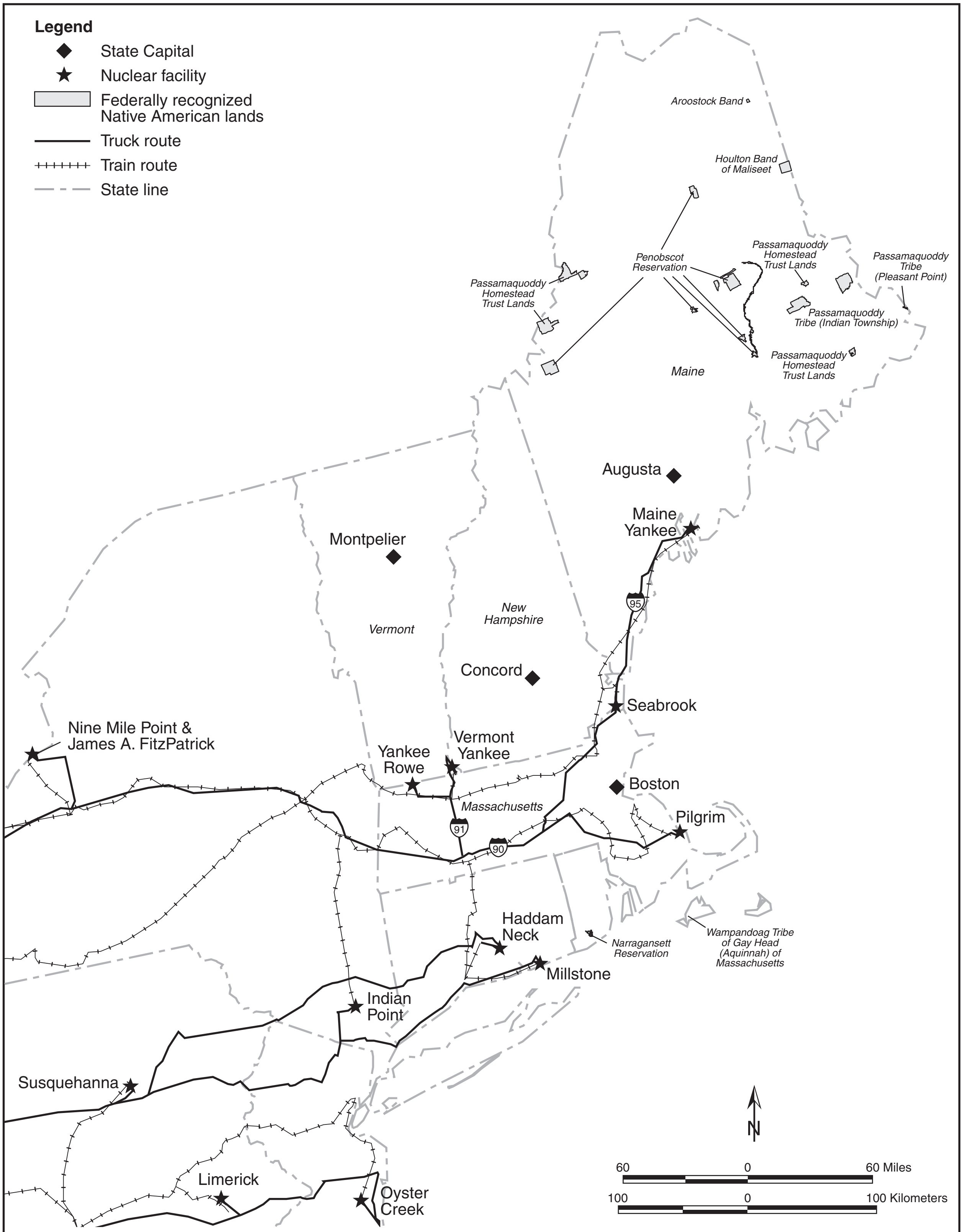


These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-45. Highway and rail routes used to analyze transportation impacts - Maine, Massachusetts, New Hampshire, and Vermont.

Table J-86. Estimated transportation impacts for the States of Minnesota and Wisconsin (page 1 of 2).

Impact category	Mostly legal-weight truck	Mostly rail: Ending rail node in Nevada: Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
MINNESOTA							
Shipments							
Truck (originating/total)	922/959	8/8	8/8	8/8	8/8	8/8	8/8
Rail (originating/total)	0/0	135/135	135/135	135/135	135/135	135/135	135/135
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$7.0\times10^{0}/3.5\times10^{-3}$	$3.1\times10^{0}/1.5\times10^{-3}$	$3.1\times10^{0}/1.5\times10^{-3}$	$3.1\times10^{0}/1.5\times10^{-3}$	$3.1\times10^{0}/1.5\times10^{-3}$	$3.1\times10^{0}/1.5\times10^{-3}$	$3.1\times10^{0}/1.5\times10^{-3}$
Workers (person-rem/LCFs)	$3.1\times10^{1}/1.2\times10^{-2}$	$9.9\times10^{0}/4.0\times10^{-3}$	$9.9\times10^{0}/4.0\times10^{-3}$	$9.9\times10^{0}/4.0\times10^{-3}$	$9.9\times10^{0}/4.0\times10^{-3}$	$9.9\times10^{0}/4.0\times10^{-3}$	$9.9\times10^{0}/4.0\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$4.1\times10^{-4}/2.1\times10^{-7}$	$2.2\times10^{-3}/1.1\times10^{-6}$	$2.2\times10^{-3}/1.1\times10^{-6}$	$2.2\times10^{-3}/1.1\times10^{-6}$	$2.2\times10^{-3}/1.1\times10^{-6}$	$2.2\times10^{-3}/1.1\times10^{-6}$	$2.2\times10^{-3}/1.1\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.5×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.1×10^{-3}	1.1×10^{-3}
Fatalities	1.4×10^{-3}	3.3×10^{-3}	3.3×10^{-3}	3.3×10^{-3}	3.3×10^{-3}	3.3×10^{-3}	3.3×10^{-3}
WISCONSIN							
Shipments							
Truck (originating/total)	996/996	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	186/186	186/186	186/186	186/186	186/186	186/186
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.1\times10^{1}/5.7\times10^{-3}$	$4.5\times10^{0}/2.2\times10^{-3}$	$4.5\times10^{0}/2.2\times10^{-3}$	$4.5\times10^{0}/2.2\times10^{-3}$	$4.5\times10^{0}/2.2\times10^{-3}$	$4.5\times10^{0}/2.2\times10^{-3}$	$4.5\times10^{0}/2.2\times10^{-3}$
Workers (person-rem/LCFs)	$3.7\times10^{1}/1.5\times10^{-2}$	$1.3\times10^{1}/5.3\times10^{-3}$	$1.3\times10^{1}/5.3\times10^{-3}$	$1.3\times10^{1}/5.3\times10^{-3}$	$1.3\times10^{1}/5.3\times10^{-3}$	$1.3\times10^{1}/5.3\times10^{-3}$	$1.3\times10^{1}/5.3\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$2.3\times10^{-3}/1.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	3.4×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.5×10^{-3}
Fatalities	0.005	0.006	0.006	0.006	0.006	0.006	0.006

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

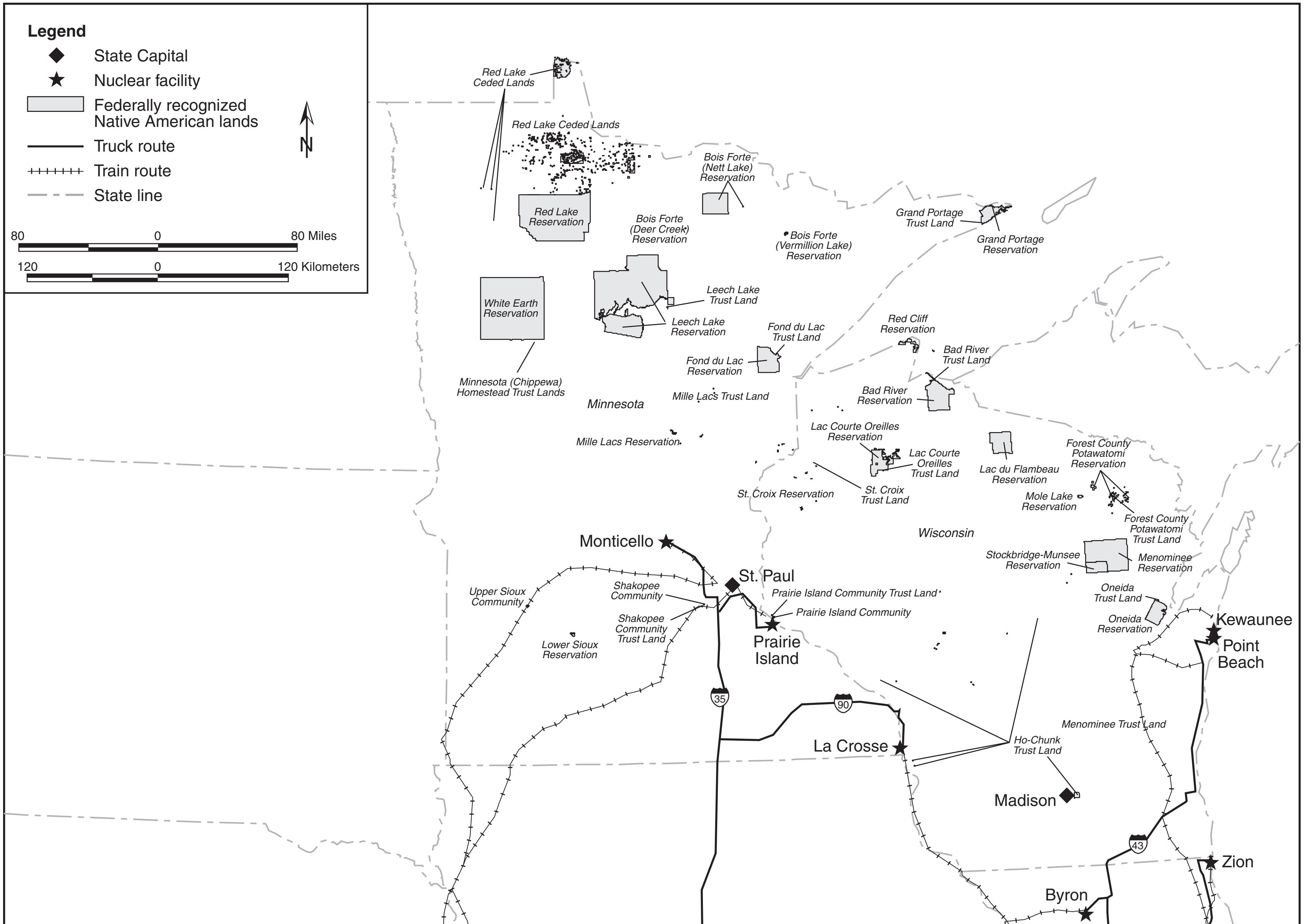
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-46. Highway and rail routes used to analyze transportation impacts - Minnesota and Wisconsin.

Table J-87. Estimated transportation impacts for the State of Missouri.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
MISSOURI							
Shipments							
Truck (originating/total)	435/19,142	0/491	0/491	0/491	0/491	0/491	0/491
Rail (originating/total)	0/0	71/4,069	71/4,069	71/4,065	71/4,126	71/4,069	71/4,069
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$3.5\times10^{2}/1.7\times10^{-1}$	$8.2\times10^{1}/4.1\times10^{-2}$	$8.2\times10^{1}/4.1\times10^{-2}$	$7.8\times10^{1}/3.9\times10^{-2}$	$8.3\times10^{1}/4.2\times10^{-2}$	$8.2\times10^{1}/4.1\times10^{-2}$	$8.2\times10^{1}/4.1\times10^{-2}$
Workers (person-rem/LCFs)	$7.5\times10^{2}/3.0\times10^{-1}$	$1.4\times10^{2}/5.5\times10^{-2}$	$1.4\times10^{2}/5.5\times10^{-2}$	$1.4\times10^{2}/5.5\times10^{-2}$	$1.4\times10^{2}/5.6\times10^{-2}$	$1.4\times10^{2}/5.5\times10^{-2}$	$1.4\times10^{2}/5.5\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$4.8\times10^{-2}/2.4\times10^{-5}$	$1.8\times10^{-2}/8.8\times10^{-6}$	$1.8\times10^{-2}/8.8\times10^{-6}$	$1.6\times10^{-2}/7.9\times10^{-6}$	$1.8\times10^{-2}/8.9\times10^{-6}$	$1.8\times10^{-2}/8.8\times10^{-6}$	$1.8\times10^{-2}/8.8\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	7.5×10^{-2}	3.8×10^{-2}	3.8×10^{-2}	3.6×10^{-2}	3.8×10^{-2}	3.8×10^{-2}	3.8×10^{-2}
Fatalities	0.28	0.086	0.086	0.085	0.086	0.086	0.086

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

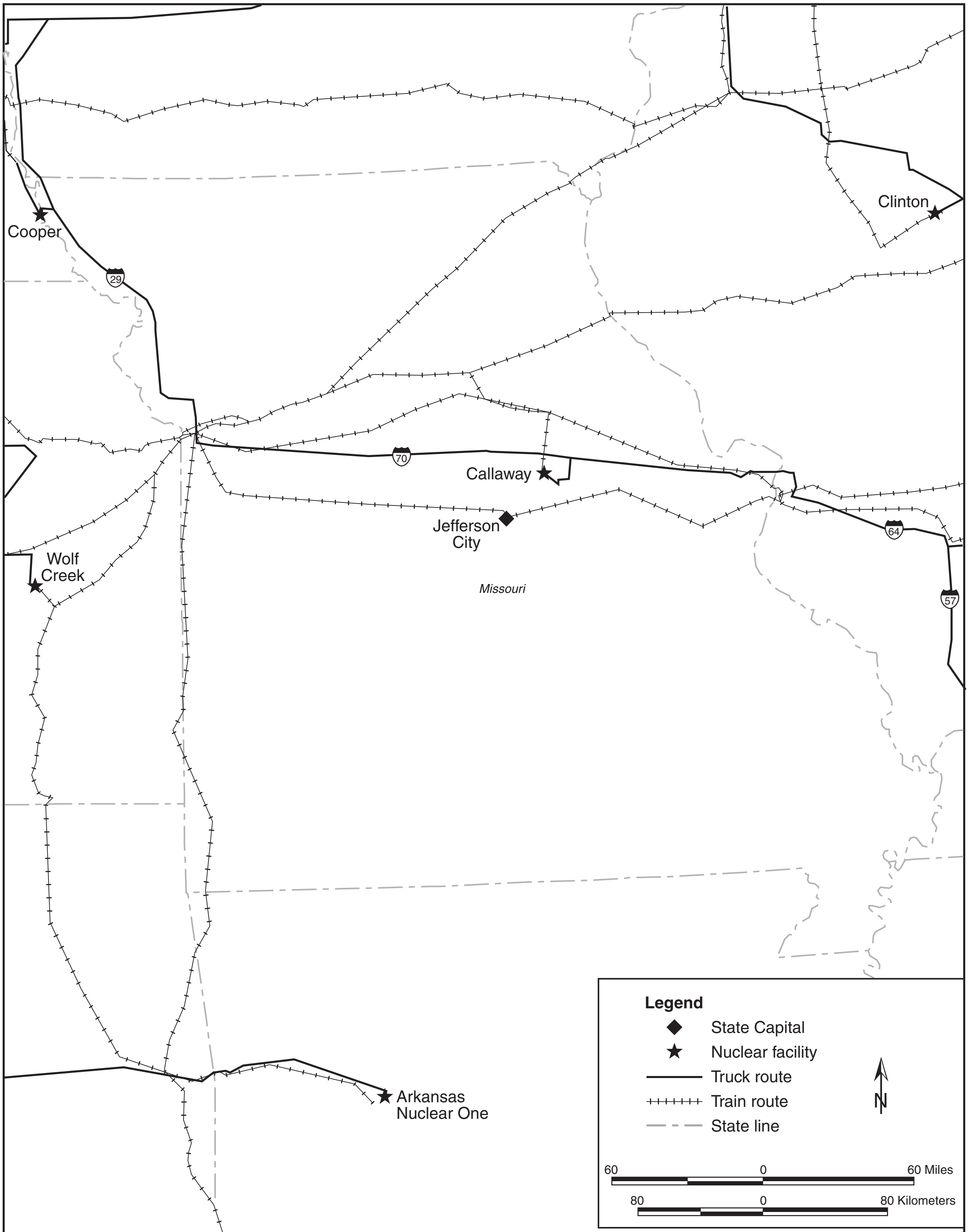
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-47. Highway and rail routes used to analyze transportation impacts - Missouri.

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Table J-88. Estimated transportation impacts for the States of Montana, North Dakota, and South Dakota (page 1 of 2).

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
MONTANA							
Shipments							
Truck (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[b]	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Workers (person-rem/LCFs)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Accident dose risk							
Population (person-rem/LCFs)	0	0	0	0	0	0	0
Nonradiological impacts							
Vehicle emissions (LCFs)	0	0	0	0	0	0	0
Fatalities	0	0	0	0	0	0	0
NORTH DAKOTA							
Shipments							
Truck (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Workers (person-rem/LCFs)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Accident dose risk							
Population (person-rem/LCFs)	0	0	0	0	0	0	0
Nonradiological impacts							
Vehicle emissions (LCFs)	0	0	0	0	0	0	0
Fatalities	0	0	0	0	0	0	0
SOUTH DAKOTA							
Shipments							
Truck (originating/total)	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/32	0/32	0/32	0/32	0/32	0/32
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$0.0\times10^{0}/0.0\times10^{0}$	$1.8\times10^{-3}/9.0\times10^{-7}$	$1.8\times10^{-3}/9.0\times10^{-7}$	$1.8\times10^{-3}/9.0\times10^{-7}$	$1.8\times10^{-3}/9.0\times10^{-7}$	$1.8\times10^{-3}/9.0\times10^{-7}$	$1.8\times10^{-3}/9.0\times10^{-7}$
Workers (person-rem/LCFs)	$0.0\times10^{0}/0.0\times10^{0}$	$4.0\times10^{-2}/1.6\times10^{-5}$	$4.0\times10^{-2}/2.0\times10^{-5}$	$4.0\times10^{-2}/1.6\times10^{-5}$	$4.0\times10^{-2}/1.6\times10^{-5}$	$4.0\times10^{-2}1.6\times10^{-5}$	$4.0\times10^{-2}/1.6\times10^{-5}$
Accident dose risk							
Population (person-rem/LCFs)	$0.0\times10^{0}/0.0\times10^{0}$	$7.3\times10^{-6}/3.7\times10^{-9}$	$7.3\times10^{-6}/3.7\times10^{-9}$	$7.3\times10^{-6}/3.7\times10^{-9}$	$7.3\times10^{-6}/3.7\times10^{-9}$	$7.3\times10^{-6}/3.7\times10^{-9}$	$7.3\times10^{-6}/3.7\times10^{-9}$
Nonradiological impacts							
Vehicle emissions (LCFs)	0.00×10^{0}	1.04×10^{-6}	1.04×10^{-6}	1.04×10^{-6}	1.04×10^{-6}	1.04×10^{-6}	1.04×10^{-6}
Fatalities	0.0×10^{0}	2.1×10^{-5}	2.1×10^{-5}	2.1×10^{-5}	2.1×10^{-5}	2.1×10^{-5}	2.1×10^{-5}

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

Table J-88. Estimated transportation impacts for the States of Montana, North Dakota, and South Dakota (page 2 of 2).

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.

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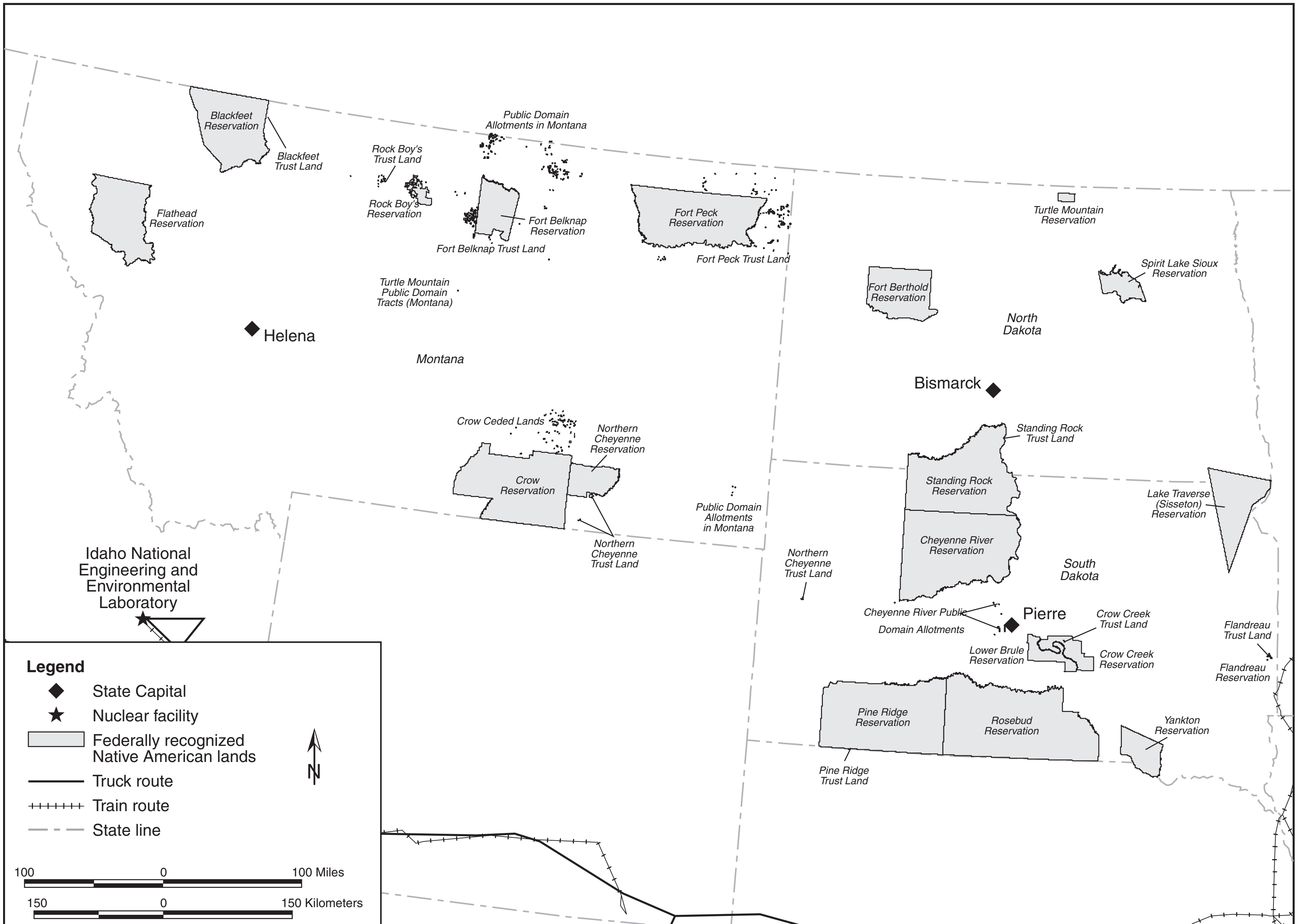


These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-48. Highway and rail routes used to analyze transportation impacts - Montana, North Dakota, and South Dakota.

Table J-89. Estimated transportation impacts for the States of New Jersey and Pennsylvania.

Impact category	Mostly legal-weight truck	Mostly rail: Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
NEW JERSEY							
Shipments							
Truck (originating/total)	1,528/3,245	0/335	0/335	0/335	0/335	0/335	0/335
Rail (originating/total)	0/0	244/244	244/244	244/244	244/244	244/244	244/244
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.2\times10^{1}/6.1\times10^{-3}$	$1.4\times10^{1}/7.1\times10^{-3}$	$1.4\times10^{1}/7.1\times10^{-3}$	$1.4\times10^{1}/7.1\times10^{-3}$	$1.4\times10^{1}/7.1\times10^{-3}$	$1.4\times10^{1}/7.1\times10^{-3}$	$1.4\times10^{1}/7.1\times10^{-3}$
Workers (person-rem/LCFs)	$4.6\times10^{1}/2.3\times10^{-2}$	$2.1\times10^{1}/1.1\times10^{-2}$	$2.1\times10^{1}/1.1\times10^{-2}$	$2.1\times10^{1}/1.1\times10^{-2}$	$2.1\times10^{1}/1.1\times10^{-2}$	$2.1\times10^{1}/1.1\times10^{-2}$	$2.1\times10^{1}/1.1\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$2.9\times10^{-3}/1.5\times10^{-6}$	$1.3\times10^{-2}/6.7\times10^{-6}$	$1.3\times10^{-2}/6.7\times10^{-6}$	$1.3\times10^{-2}/6.7\times10^{-6}$	$1.3\times10^{-2}/6.7\times10^{-6}$	$1.3\times10^{-2}/6.7\times10^{-6}$	$1.3\times10^{-2}/6.7\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	3.3×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}	3.4×10^{-3}
Fatalities	0.007	0.032	0.032	0.032	0.032	0.032	0.032
PENNSYLVANIA							
Shipments							
Truck (originating/total)	3,803/11,485	0/580	0/580	0/580	0/580	0/580	0/580
Rail (originating/total)	0/0	661/2,078	661/2,078	661/2,078	661/2,078	661/2,078	661/2,078
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.0\times10^{2}/5.1\times10^{-2}$	$9.1\times10^{1}/4.5\times10^{-2}$	$9.1\times10^{1}/4.5\times10^{-2}$	$9.1\times10^{1}/4.5\times10^{-2}$	$9.1\times10^{1}/4.5\times10^{-2}$	$9.1\times10^{1}/4.5\times10^{-2}$	$9.1\times10^{1}/4.5\times10^{-2}$
Workers (person-rem/LCFs)	$3.1\times10^{2}/1.5\times10^{-1}$	$1.1\times10^{2}/5.6\times10^{-2}$	$1.1\times10^{2}/5.6\times10^{-2}$	$1.1\times10^{2}/5.6\times10^{-2}$	$1.1\times10^{2}/5.6\times10^{-2}$	$1.1\times10^{2}/5.6\times10^{-2}$	$1.1\times10^{2}/5.6\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$1.0\times10^{-2}/5.1\times10^{-6}$	$5.5\times10^{-2}/2.7\times10^{-5}$	$5.5\times10^{-2}/2.7\times10^{-5}$	$5.5\times10^{-2}/2.7\times10^{-5}$	$5.5\times10^{-2}/2.7\times10^{-5}$	$5.5\times10^{-2}/2.7\times10^{-5}$	$5.5\times10^{-2}/2.7\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.3×10^{-2}	2.9×10^{-2}	2.9×10^{-2}	2.9×10^{-2}	2.9×10^{-2}	2.9×10^{-2}	2.9×10^{-2}
Fatalities	0.100	0.086	0.086	0.086	0.086	0.086	0.086

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

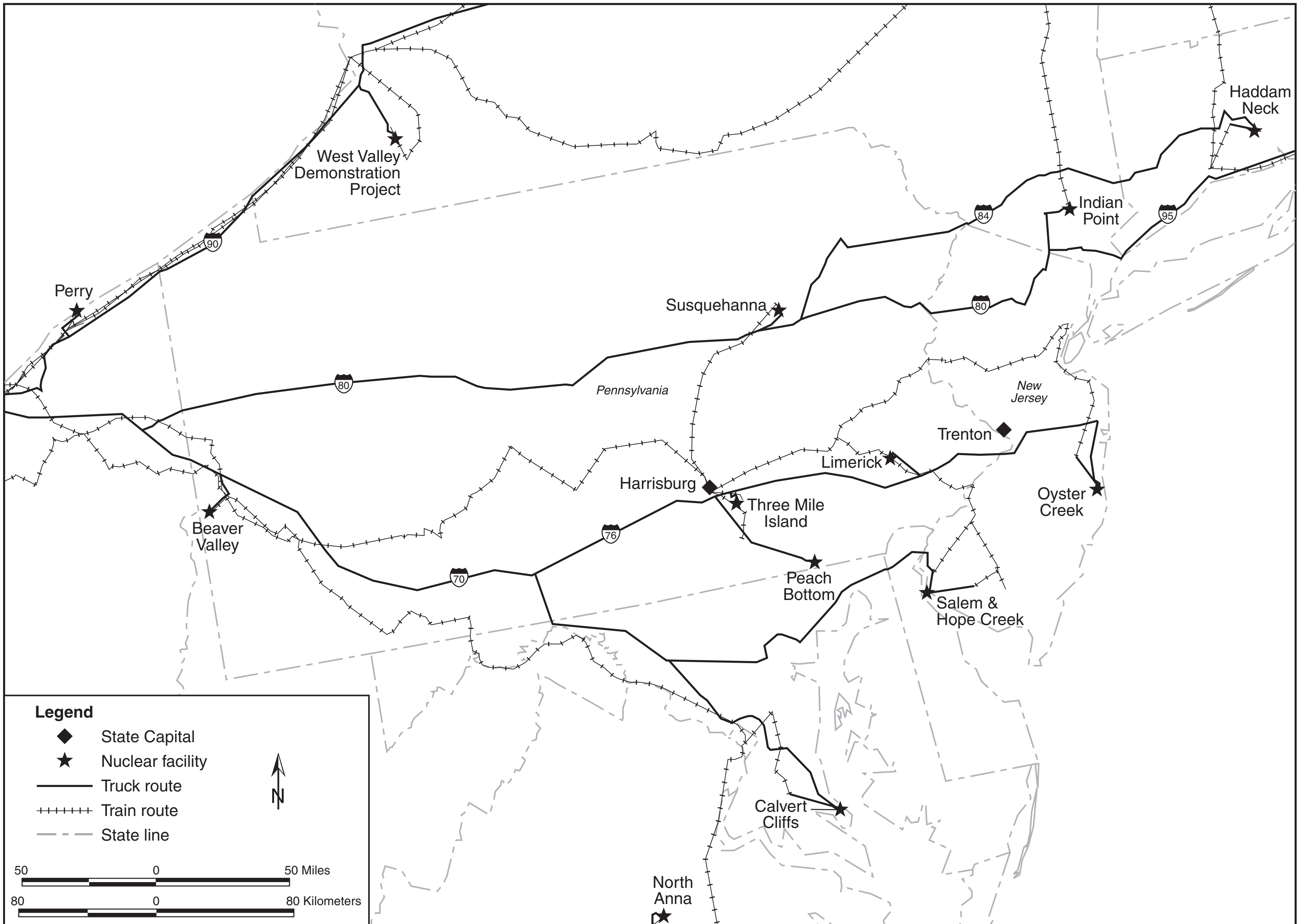
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-49. Highway and rail routes used to analyze transportation impacts - New Jersey and Pennsylvania.

Table J-90. Estimated transportation impacts for the States of North Carolina and South Carolina.

Impact category	Mostly legal-weight truck	Mostly rail: Ending rail node in Nevada[a] Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
NORTH CAROLINA							
Shipments							
Truck (originating/total)	1,871/2,508	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	486/943	486/943	486/943	486/943	486/943	486/943
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$2.7\times10^{1}/1.4\times10^{-2}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$	$1.1\times10^{1}/5.7\times10^{-3}$
Workers (person-rem/LCFs)	$8.4\times10^{1}/3.4\times10^{-2}$	$3.4\times10^{1}/1.4\times10^{-2}$	$3.4\times10^{1}/1.4\times10^{-2}$	$3.4\times10^{1}/1.4\times10^{-2}$	$3.4\times10^{1}/1.4\times10^{-2}$	$3.4\times10^{1}/1.4\times10^{-2}$	$3.4\times10^{1}/1.4\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$3.5\times10^{-3}/1.7\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$	$4.2\times10^{-3}/2.1\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	6.3×10^{-3}	4.1×10^{-3}	4.1×10^{-3}	4.1×10^{-3}	4.1×10^{-3}	4.1×10^{-3}	4.1×10^{-3}
Fatalities	0.023	0.052	0.052	0.052	0.052	0.052	0.052
SOUTH CAROLINA							
Shipments							
Truck (originating/total)	9,832/9,832	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	1,899/2,385	1,899/2,385	1,899/2,385	1,899/2,385	1,899/2,385	1,899/2,385
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$1.3\times10^{1}/6.5\times10^{-3}$	$1.8\times10^{1}/8.9\times10^{-3}$	$1.8\times10^{1}/8.9\times10^{-3}$	$1.8\times10^{1}/8.9\times10^{-3}$	$1.8\times10^{1}/8.9\times10^{-3}$	$1.8\times10^{1}/8.9\times10^{-3}$	$1.8\times10^{1}/8.9\times10^{-3}$
Workers (person-rem/LCFs)	$2.1\times10^{2}/8.4\times10^{-2}$	$1.1\times10^{2}/4.3\times10^{-2}$	$1.1\times10^{2}/4.3\times10^{-2}$	$1.1\times10^{2}/4.3\times10^{-2}$	$1.1\times10^{2}/4.3\times10^{-2}$	$1.1\times10^{2}/4.3\times10^{-2}$	$1.1\times10^{2}/4.3\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$1.1\times10^{-3}/5.4\times10^{-7}$	$4.6\times10^{-3}/2.3\times10^{-6}$	$4.6\times10^{-3}/2.3\times10^{-6}$	$4.6\times10^{-3}/2.3\times10^{-6}$	$4.6\times10^{-3}/2.3\times10^{-6}$	$4.6\times10^{-3}/2.3\times10^{-6}$	$4.6\times10^{-3}/2.3\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.4×10^{-3}	4.3×10^{-3}	4.3×10^{-3}	4.3×10^{-3}	4.3×10^{-3}	4.3×10^{-3}	4.3×10^{-3}
Fatalities	0.03	0.08	0.08	0.08	0.08	0.08	0.08

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

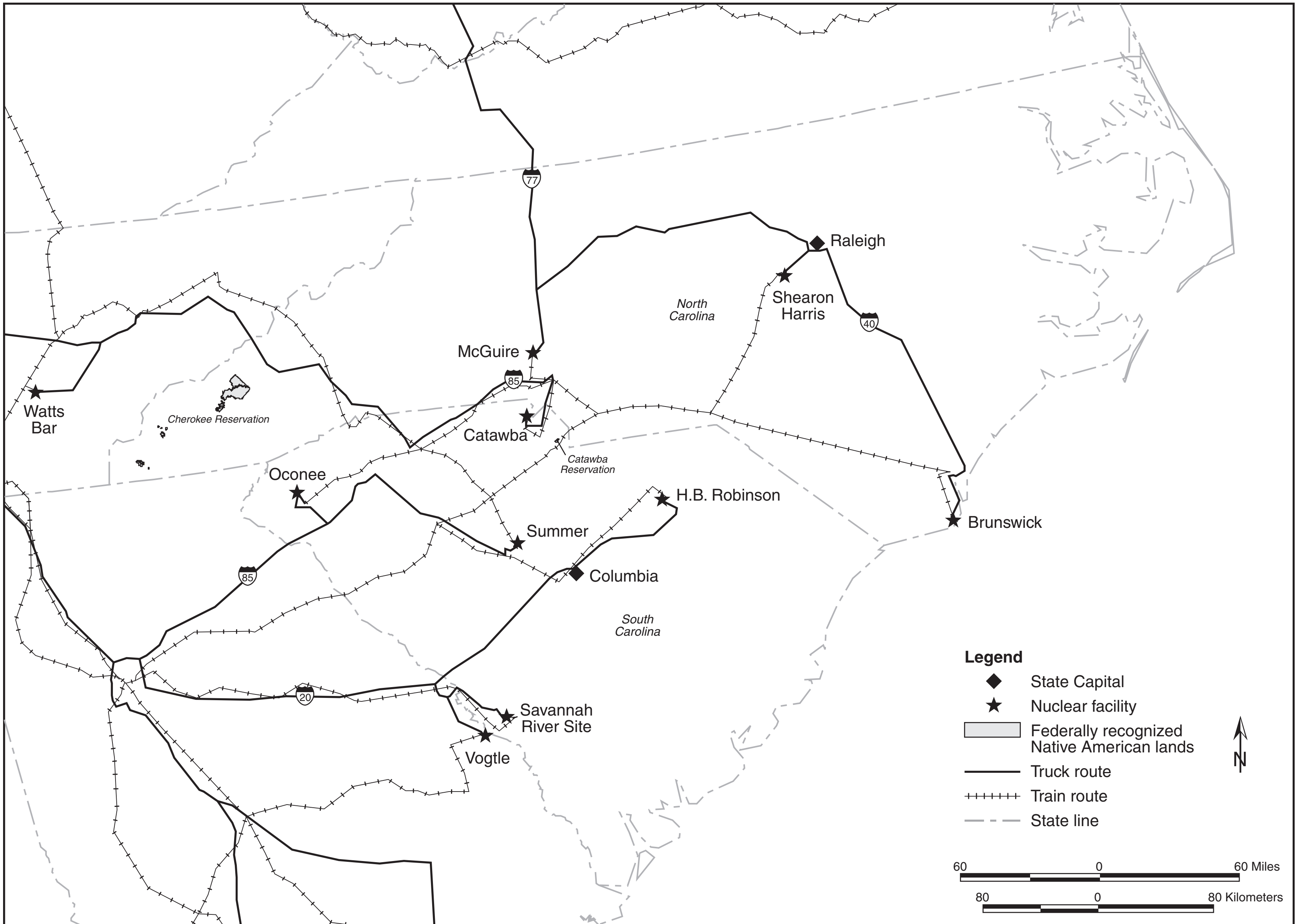
d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-50. Highway and rail routes used to analyze transportation impacts - North Carolina and South Carolina.

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Table J-91. Estimated transportation impacts for the States of Oklahoma and Texas.

Impact category	Mostly legal-weight truck	Mostly rail: Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
OKLAHOMA							
Shipments							
Truck (originating/total)	0/3,471	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	0/412	0/355	0/399	0/439	0/478	0/201
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$4.1\times10^{1}/2.0\times10^{-2}$	$4.1\times10^{-1}/2.0\times10^{-4}$	$4.1\times10^{-1}/2.0\times10^{-4}$	$3.3\times10^{-1}/1.6\times10^{-4}$	$5.2\times10^{-1}2.6\times10^{-4}$	$4.0\times10^{-1}/2.0\times10^{-4}$	$4.0\times10^{-1}/2.0\times10^{-4}$
Workers (person-rem/LCFs)	$1.1\times10^{2}/4.2\times10^{-2}$	$3.9\times10^{0}/1.5\times10^{-3}$	$3.6\times10^{0}/1.4\times10^{-3}$	$5.3\times10^{0}/2.1\times10^{-3}$	$4.5\times10^{0}/1.8\times10^{-3}$	$3.0\times10^{0}/1.7\times10^{-3}$	$3.0\times10^{0}/1.2\times10^{-3}$
Accident dose risk							
Population (person-rem/LCFs)	$2.6\times10^{-3}/1.3\times10^{-6}$	$3.4\times10^{-4}/1.7\times10^{-7}$	$3.4\times10^{-4}/1.7\times10^{-7}$	$3.1\times10^{-4}/1.6\times10^{-7}$	$4.2\times10^{-4}/2.1\times10^{-7}$	$3.5\times10^{-4}/1.7\times10^{-7}$	$3.3\times10^{-4}/1.6\times10^{-7}$
Nonradiological impacts							
Vehicle emissions (LCFs)	6.4×10^{-3}	2.3×10^{-4}	2.3×10^{-4}	1.8×10^{-4}	2.9×10^{-4}	2.3×10^{-4}	2.3×10^{-4}
Fatalities	0.043	0.005	0.005	0.007	0.006	0.006	0.004
TEXAS							
Shipments							
Truck (originating/total)	1,193/3,999	0/0	0/0	0/0	0/0	0/0	0/0
Rail (originating/total)	0/0	269/472	269/472	269/952	269/472	269/472	269/472
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$7.9\times10^{1}/4.0\times10^{-2}$	$1.8\times10^{1}/9.1\times10^{-3}$	$1.9\times10^{1}/9.3\times10^{-3}$	$4.1\times10^{1}/2.0\times10^{-2}$	$1.9\times10^{1}/9.6\times10^{-3}$	$1.8\times10^{1}/9.0\times10^{-3}$	$2.1\times10^{1}/1.0\times10^{-2}$
Workers (person-rem/LCFs)	$1.9\times10^{2}/7.6\times10^{-2}$	$4.4\times10^{1}/1.8\times10^{-2}$	$4.5\times10^{1}/1.8\times10^{-2}$	$8.2\times10^{1}/3.3\times10^{-2}$	$3.9\times10^{1}/1.5\times10^{-2}$	$4.3\times10^{1}/1.7\times10^{-2}$	$4.8\times10^{1}/1.9\times10^{-2}$
Accident dose risk							
Population (person-rem/LCFs)	$1.7\times10^{-2}/8.6\times10^{-6}$	$7.0\times10^{-3}/3.5\times10^{-6}$	$7.3\times10^{-3}/3.7\times10^{-6}$	$2.0\times10^{-2}/9.9\times10^{-6}$	$7.2\times10^{-3}/3.6\times10^{-6}$	$7.1\times10^{-3}/3.5\times10^{-6}$	$8.1\times10^{-3}/4.0\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	1.96×10^{-2}	7.47×10^{-3}	7.77×10^{-3}	1.87×10^{-2}	8.10×10^{-3}	7.60×10^{-3}	8.84×10^{-3}
Fatalities	0.07	0.05	0.05	0.14	0.04	0.05	0.05

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.

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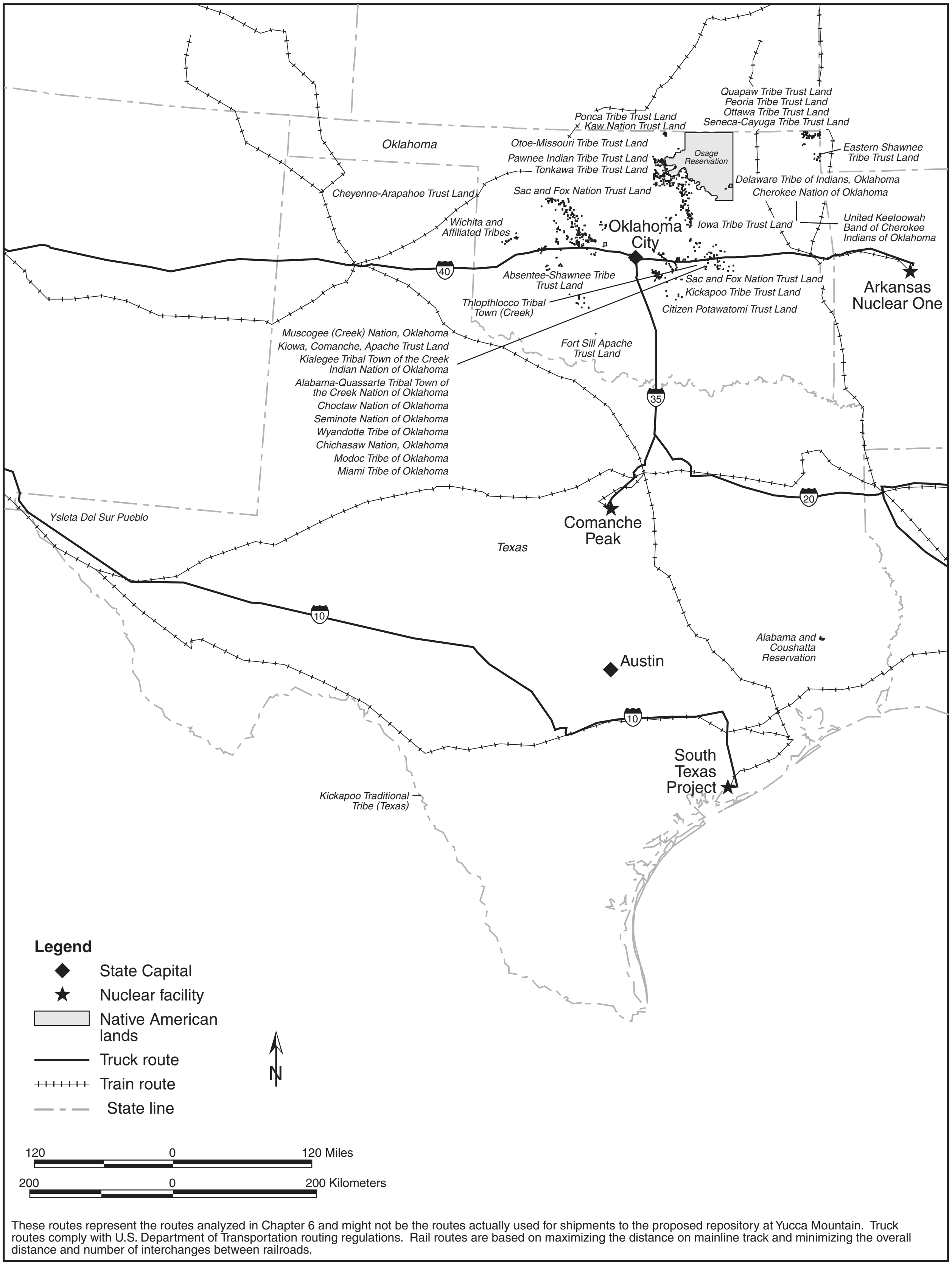

Figure J-51. Highway and rail routes used to analyze transportation impacts - Oklahoma and Texas.

Table J-92. Estimated transportation impacts for the States of Utah and Wyoming.

Impact category	Mostly legal-weight truck	Mostly rail					
		Ending rail node in Nevada[a]					
		Caliente[b]	Dry Lake[c]	Jean[d]	Beowawe[e]	Eccles[f]	Apex[g]
UTAH							
Shipments							
Truck (originating/total)	0/45,919	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079
Rail (originating/total)	0/300	0/8,986	0/8,896	0/8,182	0/9,134	0/9,052	0/8,742
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$9.6\times10^{2}/4.8\times10^{-1}$	$1.8\times10^{2}/8.8\times10^{-2}$	$1.8\times10^{2}/8.8\times10^{-2}$	$1.1\times10^{3}/5.6\times10^{-1}$	$1.8\times10^{2}/8.8\times10^{-2}$	$1.8\times10^{2}/8.8\times10^{-2}$	$1.7\times10^{2}/8.6\times10^{-2}$
Workers (person-rem/LCFs)	$1.9\times10^{3}/7.4\times10^{-1}$	$3.6\times10^{2}/1.4\times10^{-1}$	$3.6\times10^{2}/1.4\times10^{-1}$	$2.2\times10^{3}/8.8\times10^{-1}$	$3.6\times10^{2}/1.4\times10^{-1}$	$3.6\times10^{2}/1.4\times10^{-1}$	$3.6\times10^{2}/1.4\times10^{-1}$
Accident dose risk							
Population (person-rem/LCFs)	$1.0\times10^{-1}/5.2\times10^{-5}$	$7.2\times10^{-2}/3.6\times10^{-5}$	$7.2\times10^{-2}/3.6\times10^{-5}$	$1.8\times10^{-1}/8.8\times10^{-5}$	$7.2\times10^{-2}/3.6\times10^{-5}$	$7.2\times10^{-2}/3.6\times10^{-5}$	$7.2\times10^{-2}/3.6\times10^{-5}$
Nonradiological impacts							
Vehicle emissions (LCFs)	2.8×10^{-1}	8.7×10^{-2}	8.7×10^{-2}	3.6×10^{-1}	8.7×10^{-2}	8.7×10^{-2}	8.4×10^{-2}
Fatalities	0.71	0.58	0.58	1.25	0.58	0.58	0.57
WYOMING							
Shipments							
Truck (originating/total)	0/41,507	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079
Rail (originating/total)	0/0	0/7,347	0/7,347	0/7,065	0/7,440	0/7,347	0/7,347
Radiological impacts							
Incident-free impacts							
Population (person-rem/LCFs)[h]	$5.4\times10^{2}/2.7\times10^{-1}$	$4.4\times10^{1}/2.2\times10^{-2}$	$4.4\times10^{1}/2.2\times10^{-2}$	$4.3\times10^{1}/2.1\times10^{-2}$	$4.4\times10^{1}/2.2\times10^{-2}$	$4.4\times10^{1}/2.2\times10^{-2}$	$4.4\times10^{1}/2.2\times10^{-2}$
Workers (person-rem/LCFs)	$1.7\times10^{3}/6.9\times10^{-1}$	$3.8\times10^{2}/1.5\times10^{-1}$	$3.8\times10^{2}/1.5\times10^{-1}$	$3.7\times10^{2}/1.5\times10^{-1}$	$3.8\times10^{2}/1.5\times10^{-1}$	$3.8\times10^{2}/1.5\times10^{-1}$	$3.8\times10^{2}/1.5\times10^{-1}$
Accident dose risk							
Population (person-rem/LCFs)	$3.9\times10^{-2}/1.9\times10^{-5}$	$7.1\times10^{-3}/3.6\times10^{-6}$	$7.1\times10^{-3}/3.6\times10^{-6}$	$6.8\times10^{-3}/3.4\times10^{-6}$	$7.2\times10^{-3}/3.6\times10^{-6}$	$7.1\times10^{-3}/3.6\times10^{-6}$	$7.1\times10^{-3}/3.6\times10^{-6}$
Nonradiological impacts							
Vehicle emissions (LCFs)	38.7×10^{-3}	15.9×10^{-3}	15.9×10^{-3}	15.4×10^{-3}	16.1×10^{-3}	15.9×10^{-3}	15.9×10^{-3}
Fatalities	0.58	0.06	0.06	0.06	0.06	0.06	0.06

a. Under the mostly rail scenario, rail shipments would arrive in Nevada at one of six existing rail nodes. Impacts would vary according to the node. From that node, DOE would use one of the rail or heavy-haul implementing alternatives to complete the transportation to Yucca Mountain (see Section J.1.2).

b. For heavy-haul truck transportation, the Caliente junction is the location of the proposed Caliente intermodal transfer station for heavy-haul trucks near the town of Caliente in eastern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on one of the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas routes. For branch rail line transportation, railcars would transfer via the Caliente Option to the Caliente Corridor at the Caliente junction.

c. For heavy-haul truck transportation, the Dry Lake junction is near the location of the proposed Apex/Dry Lake intermodal transfer station for heavy-haul trucks in southeast Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Apex/Dry Lake route.

d. For heavy-haul truck transportation, the Jean junction is near the location of the proposed Sloan/Jean intermodal transfer station for heavy-haul trucks in southern Nevada. Rail shipments terminating at this junction would continue to Yucca Mountain on heavy-haul trucks on the Sloan/Jean route. For branch rail line transportation, railcars would transfer from the mainline railroad via the Wilson Pass or Stateline Pass Option of the Jean Corridor, near the Jean junction.

e. For branch rail line transportation, railcars would transfer from the mainline railroad at the Beowawe junction in north-central Nevada to the Carlin Corridor.

f. For branch rail line transportation, railcars would transfer from the mainline railroad at the Eccles junction east of Caliente, Nevada, via the Eccles Option or nearby via the Crestline Option of the Caliente or Caliente-Chalk Mountain Corridor. Impacts in states outside Nevada would be the same for the Eccles and Crestline Options of the Caliente and Caliente-Chalk Mountain Corridors.

g. For branch rail line transportation, railcars would transfer from the mainline railroad at the Apex junction in southeast Nevada, possibly via the Valley Connection, to the Valley Modified Corridor.

h. LCF = latent cancer fatality.

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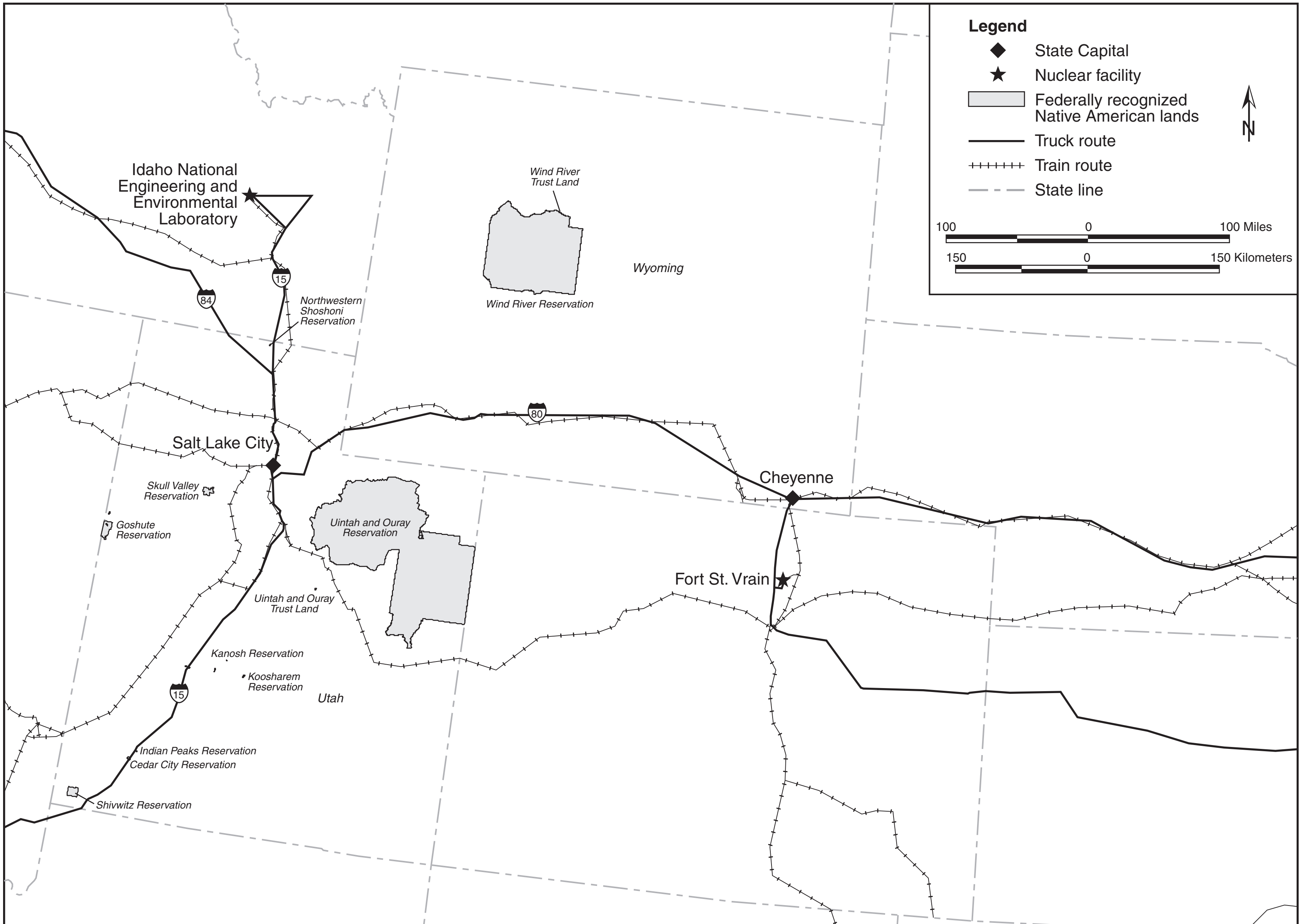


These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

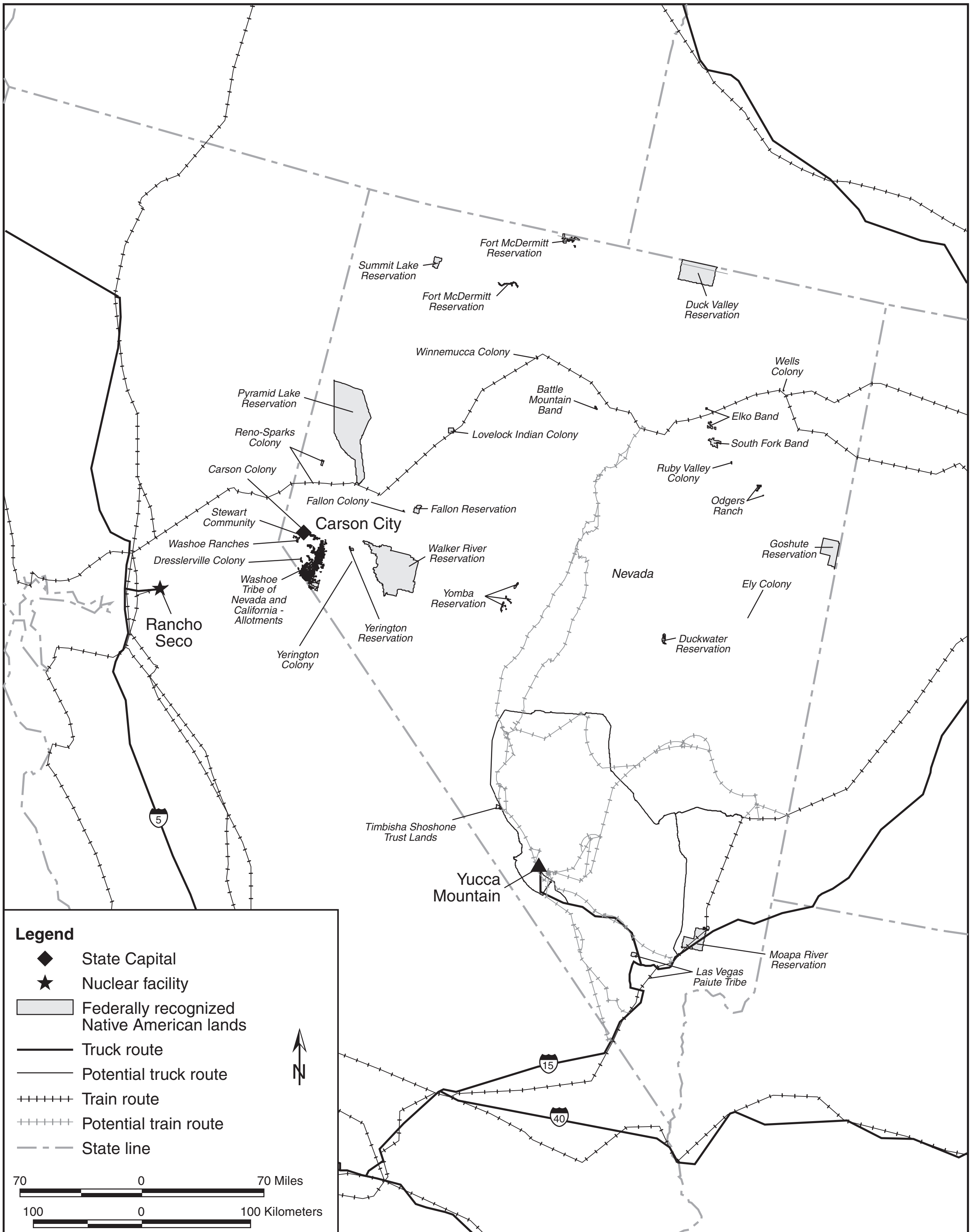
Figure J-52. Highway and rail routes used to analyze transportation impacts - Utah and Wyoming.

Table J-93. Estimated transportation impacts for the State of Nevada.

Impact category	Mostly legal-weight truck	Mostly rail									
		Rail implementing alternatives					Heavy-haul implementing alternatives				
		Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake
NEVADA											
Shipments											
Truck (originating/total)	0/52,786	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079	0/1,079
Rail (originating/total)	0/300	0/9,646	0/9,646	0/9,646	0/9,646	0/9,646	0/9,646	0/9,646	0/9,646	0/9,646	0/9,646
Radiological impacts											
Incident-free impacts											
Population (person-rem/LCFs)[a]	3.5×10^{2}/ 1.8×10^{-1}	1.9×10^{1}/ 9.4×10^{-3}	3.8×10^{1}/ 1.9×10^{-2}	1.8×10^{1}/9.1×10^{-3}	1.6×10^{2}/ 7.8×10^{-2}	2.6×10^{1}/ 1.3×10^{-2}	7.6×10^{1}/ 3.8×10^{-2}	$6.1 \times 101/3 \times 10^{-2}$	2.2×10^{2}/ 1.1×10^{-1}	3.0×10^{2}/ 1.5×10^{-1}	1.5×10^{2}/ 7.7×10^{-2}
Workers (person-rem/LCFs)	1.9×10^{3}/ 7.5×10^{-1}	8.3×10^{2}/ 3.3×10^{-1}	9.6×10^{2}/ 3.8×10^{-1}	7.3×10^{2}/2.9×10^{-1}	7.4×10^{2}/ 3.0×10^{-1}	7.0×10^{2}/ 2.8×10^{-1}	1.4×10^{3}/ 5.5×10^{-1}	9.8×10^{2}/3.9×10^{-1}	1.1×10^{3}/ 4.5×10^{-1}	9.3×10^{2}/ 3.7×10^{-1}	8.8×10^{2}/ 3.5×10^{-1}
Accident dose risk											
Population (person-rem/LCFs)	5.3×10^{-2}/ 2.6×10^{-5}	1.7×10^{-3}/ 8.6×10^{-7}	2.6×10^{-3}/ 1.3×10^{-6}	1.7×10^{-3}/8.5×10^{-7}	7.1×10^{-3}/ 3.6×10^{-6}	2.1×10^{-3}/ 1.0×10^{-6}	1.0×10^{-2}/ 5.0×10^{-6}	$1.9 \times 10^{-3} 9.5 \times 10^{-7}$	5.6×10^{-2}/ 2.8×10^{-5}	1.2×10^{-1}/ 6.0×10^{-5}	5.6×10^{-2}/ 2.8×10^{-5}
Nonradiological impacts											
Vehicle emissions (LCFs)	9.2×10^{-2}	7.1×10^{-3}	1.8×10^{-2}	7.7×10^{-3}	7.7×10^{-2}	1.1×10^{-2}	1.0×10^{-2}	1.9×10^{-3}	5.6×10^{-2}	1.8×10^{-1}	6.5×10^{-2}
Fatalities	0.49	0.07	0.09	0.06	0.06	0.09	0.60	0.33	0.43	0.25	0.23

a. Includes impacts of an intermodal transfer station.

b. LCF = latent cancer fatality.



These routes represent the routes analyzed in Chapter 6 and might not be the routes actually used for shipments to the proposed repository at Yucca Mountain. Truck routes comply with U.S. Department of Transportation routing regulations. Rail routes are based on maximizing the distance on mainline track and minimizing the overall distance and number of interchanges between railroads.

Figure J-53. Highway and rail routes used to analyze transportation impacts - Nevada.

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Note: In an effort to ensure consistency among Yucca Mountain Site Characterization Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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Appendix K

Long-Term Radiological Impact Analysis for the No-Action Alternative

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APPENDIX K. LONG-TERM RADIOLOGICAL IMPACT ANALYSIS FOR THE NO-ACTION ALTERNATIVE

K.1 Introduction

This appendix provides detailed information related to the radiological impact analysis for No-Action Alternative Scenario 2, including descriptions of the conceptual models used for facility degradation, spent nuclear fuel and high-level radioactive waste material degradation, and data input parameters. In addition, this appendix discusses the computer programs and exposure calculations used. The methods described include summaries of models and programs used for radioactive material release, environmental transport, radiation dose, and radiological human health impact assessment. Although the appendix describes No-Action Scenario 1, it focuses primarily on the long-term (100 to 10,000 years) radiological impacts associated with Scenario 2.

NO-ACTION ALTERNATIVE SCENARIOS 1 AND 2

Under the Nuclear Waste Policy Act, the Federal Government has the responsibility to provide permanent disposal of spent nuclear fuel and high-level radioactive waste to protect the public's health and safety and the environment. DOE intends to comply with the terms of existing consent orders and compliance agreements on the management of spent nuclear fuel and high-level radioactive waste. However, the course that Congress, DOE, and the commercial nuclear utilities would take if there was no recommendation to use Yucca Mountain as a repository is highly uncertain.

In light of these uncertainties, it would be speculative to attempt to predict precise consequences. To illustrate one set of possibilities, however, DOE decided to focus the analysis of the No-Action Alternative on the potential impacts of two scenarios:

Scenario 1: Long-term storage of spent nuclear fuel and high-level radioactive waste at the current storage sites, with effective institutional control for at least 10,000 years.

Scenario 2: Long-term storage of spent nuclear fuel and high-level radioactive waste, with the assumption of no effective institutional control after approximately 100 years.

DOE recognizes that neither of these scenarios is likely to occur if there was a decision to not develop a repository at Yucca Mountain. However, the Department selected these two scenarios for analysis because they provide a baseline for comparison to the impacts from the Proposed Action and because they reflect a range of the potential impacts that could occur.

To permit a comparison of the impacts between the construction, operation and monitoring, and eventual closure of a proposed repository at Yucca Mountain and No-Action Scenario 2, the U.S. Department of Energy (DOE) took care to maintain consistency, where possible, with the modeling techniques used to conduct the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998, all) and in the *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document* (DIRS 100355, 100356, 100357, 100358, 100359, 100362, 100364, 100365, 100366, 100369, 100371-CRWMS M&O 1998, all) for the proposed repository (see Appendix I, Section I.1, for details). In pursuit of this goal, DOE structured this analysis to facilitate an impact comparison with the repository impact analysis. Important consistencies include the following:

- Identical evaluation periods (100 years and 10,000 years)

- Identical spent nuclear fuel and high-level radioactive waste inventories at the reference repository:
  - — Proposed Action: 63,000 metric tons of heavy metal (MTHM) of commercial spent nuclear fuel; 2,333 MTHM of DOE spent nuclear fuel; 8,315 canisters of high-level radioactive waste. This inventory includes an amount of surplus weapons-usable plutonium
  - — Module 1: All Proposed Action materials, plus an additional 42,000 MTHM of commercial spent nuclear fuel; 167 MTHM of DOE spent nuclear fuel; and 13,965 canisters of high-level radioactive waste. This would result in a total of approximately 105,000 MTHM of commercial spent nuclear fuel; 2,500 MTHM of DOE spent nuclear fuel; and 22,280 canisters of high-level radioactive waste. This inventory also includes the surplus weapons-usable plutonium (see Appendix A, Figure A-2)

DEFINITION OF METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

- Consistent spent nuclear fuel and high-level radioactive waste corrosion and dissolution models
- Identical radiation dose and risk conversion factors
- Similar assumptions regarding the future habits and behaviors of population groups (that is, that they will not be much different from those of populations today)

Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would improve long-term repository performance and reduce uncertainty. The result of the design evolution process was the development of the flexible design (DIRS 153849-DOE 2001, all), which was evaluated in the Supplement to the Draft EIS. This design focuses on controlling the temperature of the rock between waste emplacement drifts. As a result of these design changes, this Final EIS evaluates a range of repository operating modes (higher- and lower-temperature). The lower-temperature operating mode has the flexibility to remain open and under active institutional control for up to 300 years after emplacement. Although Chapter 4 of this EIS includes an evaluation of impacts for this period, DOE did not evaluate the 300-year institutional control case for the No-Action Alternative. The primary reason for not updating this part of the analysis was because if the institutional control period for the analysis of the No-Action Alternative were extended to 300 years, the short-term environmental impacts would have increased by as much as 3 times. DOE did not want to appear to overstate the impacts from the No-Action Alternative.

Since the publication of the Draft EIS, DOE modified the spent nuclear fuel cladding corrosion rates and failure mechanisms used in the performance analysis in Chapter 5 of the Final EIS. DOE did not update these models for the No-Action Alternative Scenario 2 analysis because the outcome would have been an increase in the long-term radiation doses and potential health impacts, however, the increase would be within the uncertainties discussed in Section K.4. In addition, the radionuclide inventories for commercial spent nuclear fuel were updated for the Final EIS (see Appendix A, Tables A-8 and A-9) to reflect the higher initial enrichments and burnup projected for commercial nuclear facilities. Although these revised inventories were used to estimate potential short-term repository impacts in the Final EIS

(Chapter 4), DOE chose not to update the No-Action inventories because, again, the effect on the outcome would be about a 15-percent increase in health impacts in this chapter.

Affected populations for the No-Action Alternative were, in general, based on 1990 census estimates and not projected to 2035 as was done for the Proposed Action. However, if the population across the Nation had been projected to 2035, the collective impacts resulting from radiation exposure would have increased by less than a factor of 1.5, which is the average expected increase in national population from 1990 to 2035 (DIRS 152471-Bureau of the Census 2000, all).

For commercial facilities, the No-Action analysis estimated short- and long-term radiological impacts for Scenario 1 and short-term impacts for Scenario 2 during the first 100 years for facility workers and the public based on values provided by the U.S. Nuclear Regulatory Commission (DIRS 101898-NRC 1991, p. 21). For DOE facilities, radiological impacts for these periods under Scenarios 1 and 2 were estimated based on analysis by Orthen (DIRS 104596-Orthen 1999, all). To ensure consistency with the repository impact analysis, the long-term facility degradation and environmental releases of radioactive materials were estimated by adapting TSPA-VA process models developed to predict the behavior of spent nuclear fuel and high-level radioactive waste in the repository (DIRS 104597-Battelle 1998, pp. 2.4 to 2.9).

Because DOE did not want to influence the results to favor the repository, it used assumptions that generally resulted in lower predicted impacts (rather than applying the bounding assumptions used in many of the repository impact analyses) if TSPA-VA models were not available or not appropriate for this continuous storage analysis. For example, the No-Action Scenario 2 analysis took into account the protectiveness of the stainless-steel waste canister when estimating releases of radioactive material from the vitrified high-level radioactive waste; the TSPA-VA assumed no credit for material protection or radionuclide retardation by the intact canister. This approach dramatically reduced the release rate of high-level radioactive waste materials to the environment, thereby resulting in lower estimated total doses and dose rates to the exposed populations. Conversely, in many instances the TSPA-VA selected values for input parameters that defined ranges to ensure that there would be no underestimation of the associated impacts. Section K.4 discusses other consistencies and inconsistencies between the TSPA-VA and the No-Action analysis.

The long-term impact analysis used recent climate and meteorological data, assuming they would remain constant throughout the evaluation period (DIRS 101912-Poe and Wise 1998, all). DOE recognizes that there could be considerable changes in the climate over 10,000 years (precipitation patterns, ice ages, global warming, etc.) but, to simplify the analysis, did not attempt to quantify climate changes. Section K.4.1.2 discusses the difficulties of modeling these changes and the potential effect on outcomes resulting from uncertainties associated with predicting potential future climatic conditions.

Although the repository TSPA-VA used probabilistic process models to evaluate the transport of radioactive materials within Yucca Mountain and underlying groundwater aquifers, DOE used the deterministic computer program Multimedia Environmental Pollutant Assessment System (MEPAS; DIRS 101533-Buck et al. 1995, all) for the No-Action Scenario 2 analysis because of the need to model the transport of radioactive material. In addition, it discusses environmental pathways not present at the repository (for example, the movement of contaminants through surface water). The MEPAS program has been accepted and used by DOE and the Environmental Protection Agency for long-term performance assessments (DIRS 101917-Rollins 1998, pp. 1, 10, and 19).

K.2 Analytical Methods

This section describes the methodology used to evaluate the long-term degradation of the concrete facilities, steel storage containers, and spent nuclear fuel and high-level radioactive waste materials. In addition, it discusses the eventual release and transport of radioactive materials under Scenario 2. The

PROBABILISTIC AND DETERMINISTIC ANALYSES

A *probabilistic* analysis represents data input to a model as a range of values that represents the uncertainty associated with the actual or true value. The probabilistic model randomly samples these input parameter distributions many times to develop a possible range of results. The range of results provides a quantitative estimate of the uncertainty of the results.

A *deterministic* analysis uses a best estimate single value for each model input and produces a single result. The deterministic analysis will usually include a separate analysis that addresses the uncertainty associated with each input and provides an assessment of impact these uncertainties could have on the model results.

Analyses can use both approaches to provide similar information regarding the uncertainty of the results.

institutional control assumed under Scenario 1 would ensure ongoing maintenance, repair and replacement of storage facilities, and containment of spent nuclear fuel and high-level radioactive waste. For this reason, assuming the degradation of engineered barriers and the release and transport of radioactive materials is not appropriate for Scenario 1. The Scenario 2 analysis assumed that the degradation process would begin at the time when there was no effective institutional control (that is, after approximately 100 years) and the facilities would no longer be maintained. This section also describes the models and assumptions used to evaluate human exposures and potential health effects, and cost impacts.

K.2.1 GENERAL METHODOLOGY

For the No-Action analysis, the facilities, dry storage canisters, cladding, spent nuclear fuel, and high-level radioactive waste material, collectively known as the *engineered barrier system*, were modeled using an approach consistent (to the extent possible) with that developed for the Viability Assessment (DIRS 101779-DOE 1998, Volume 3). These process models were developed to evaluate, among other things, the performance of the repository engineered barrier system in the underground repository environment. In this analysis, the process models were adapted whenever feasible to evaluate surface environmental conditions at commercial and DOE sites. These models are described below.

Figure K-1 shows the modeling of the degradation of spent nuclear fuel and high-level radioactive waste and the release of radioactive materials over long periods. Five steps describe the process of spent nuclear fuel and high-level radioactive waste degradation; a sixth step, facility radioactive material release, describes the amount and rate of precipitation that would transport the radioactive material or *dissolution products* to the environment. This section describes each process and the results. Additional details are provided in reference documents (DIRS 101910-Poe 1998, all; DIRS 104597-Battelle 1998, all).

Environmental parameters important to the degradation processes include temperature, relative humidity, precipitation chemistry (pH and chemical composition), precipitation rates, number of rain-days, and freeze/thaw cycles. Other parameters considered in the degradation process describe the characteristics and behavior of the engineered barrier system, including barrier material composition and thickness. To simplify the analysis, the United States was divided into five regions (as shown in Figure K-2) for the purposes of estimating degradation rates and human health impacts (see Section K.2.1.6 for additional details).

Under the No-Action Alternative, commercial utilities would manage their spent nuclear fuel at 72 nuclear power generating facilities. DOE would manage its spent nuclear fuel and high-level radioactive waste at five DOE facilities [the Hanford Site (Region 5), the Idaho National Engineering and Environmental Laboratory (Region 5), Fort St. Vrain (Region 5), the West Valley Demonstration Project (Region 1), and the Savannah River Site (Region 2)]. The No-Action analysis evaluated DOE spent

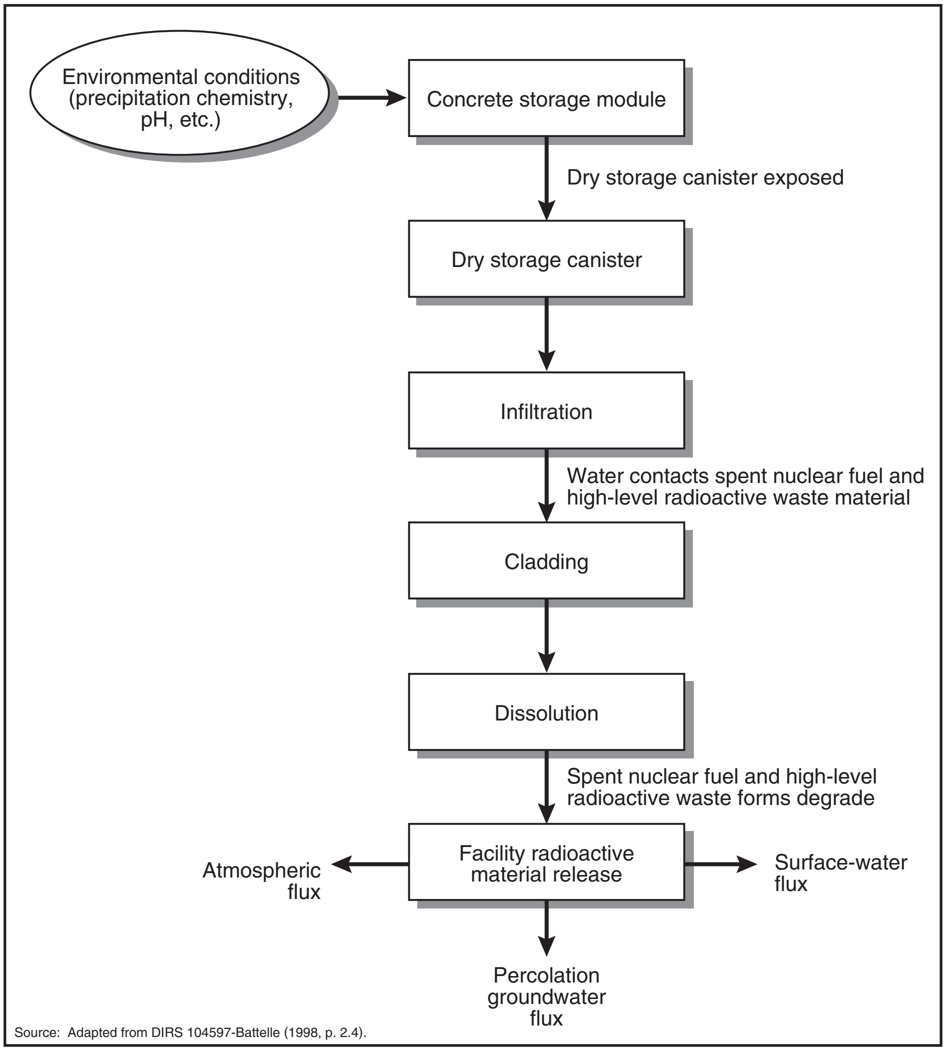
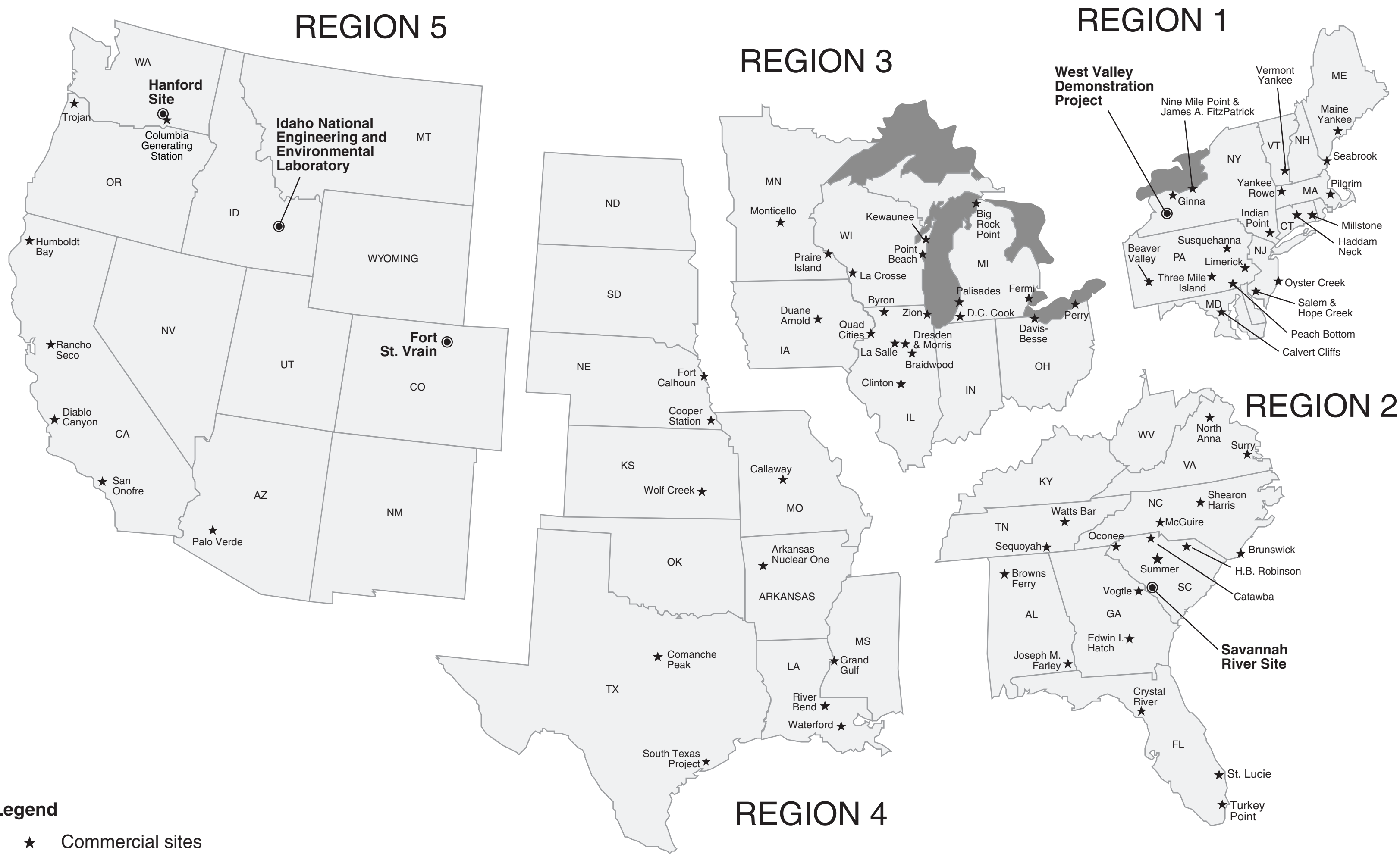


Figure K-1. Primary steps and processes involved in the degradation of the engineered barrier system.

nuclear fuel and high-level radioactive waste at the commercial and DOE sites or at locations where Records of Decision have placed or will place these materials (for example, West Valley Demonstration Project spent nuclear fuel was evaluated at the Idaho National Engineering and Environmental Laboratory (60 *FR* 28680, June 1, 1995). Therefore, the No-Action analysis evaluated DOE aluminum-clad spent nuclear fuel at the Savannah River Site and DOE non-aluminum-clad fuel at the Idaho National Engineering and Environmental Laboratory. DOE evaluated most of the Fort St. Vrain spent nuclear fuel at the Colorado site. In addition, the analysis evaluated high-level radioactive waste at the West Valley Demonstration Project, the Idaho National Engineering and Environmental Laboratory, the Hanford Site, and the Savannah River Site.

K.2.1.1 Concrete Storage Module Degradation

The first process model analyzed degradation mechanisms related to failure of the concrete storage module. *Failure* is defined as the time when precipitation would infiltrate the concrete and reach the spent nuclear fuel or high-level radioactive waste storage canister. The analysis (DIRS 101910-Poe 1998, Section 2.0) considered degradation due to exposure to the surrounding environment.



Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Symbols do not reflect precise locations.

Note: None of the facilities evaluated are located in Alaska or Hawaii.

Source: Modified from DIRS 101911-Poe (1998, p. 2).

Figure K-2. No-Action Alternative analysis regions.

The primary cause of failure of surface-mounted concrete structures is freeze/thaw cycles that cause the concrete to crack and spall (break off in layers), which allows precipitation to enter the concrete, causing more freeze damage. *Freeze/thaw failure* is defined as the time when half of the thickness of the concrete is cracked and spalled. Some regions (coastal California, Texas, Florida, etc.) are essentially without the freeze/thaw cycle. In these locations the primary failure mechanism is precipitation containing chlorides, which decompose the chemical constituents of the concrete into sand-like materials. This process progresses more slowly than the freeze/thaw process. Figure K-3 shows estimated concrete storage module failure times.

Below-grade concrete structures, such as those used to store some of the DOE spent nuclear fuel and most of the high-level radioactive waste, would be affected by the same concrete degradation mechanisms as surface facilities. Below grade, the freeze/thaw degradation would not be as great because the soil would moderate temperature fluctuations. The primary failure mechanism for below-grade facilities would be the loss of the above-grade roof, which would result in precipitation seeping around shield plugs. The analysis assumed that this would occur 50 years after the end of facility maintenance, and that this would be the reasonable life expectancy of a facility without maintenance and periodic repair (DIRS 101910-Poe 1998, pp. 4-6 to 4-19).

K.2.1.2 Storage Canister Degradation

The second process analyzed was spent nuclear fuel and high-level radioactive waste storage canister degradation. For commercial and DOE spent nuclear fuel, the analysis defined failure of the stainless-steel dry storage canister as the time at which precipitation penetrated the canister and wet the spent nuclear fuel. The analysis defined failure for the high-level radioactive waste as the time at which precipitation penetrated the canisters. This is consistent with the repository definition that failure of the waste package would occur when water penetrated the package and came in contact with the contents. The stainless-steel model used for the No-Action analysis was consistent with the waste package inner layer corrosion model used for the repository TSPA-VA (DIRS 101779-DOE 1998, Volume 3, Section 3.4) with the functional parameters modified to incorporate stainless-steel corrosion data (Section K.4.3.1 discusses the sensitivity of outcome to carbon-steel dry storage containers). In addition, the analysis used parameters appropriate for above-ground conditions, including temperature, meteorological data, and chemical constituents in the atmosphere and precipitation. Although inconsistent with the assumptions used for the TSPA-VA, the analysis took credit for the protectiveness of the high-level radioactive waste canister because (1) it is the only container between the waste material and the environment and, (2) to ignore the protectiveness of this barrier would have resulted in a considerable overestimation of impacts. This approach is consistent with the decision, in the case of the No-Action Scenario 2 analysis, to provide a realistic radionuclide release rate where possible and to preclude the overestimation of the associated radiological human health impacts.

The primary determinants of stainless-steel corrosion for the different regions are the amount, the acidity, and the chloride concentration of the precipitation. The storage canisters degrade faster in the below-grade storage configuration than on the surface due to the higher humidity in the below-grade environment. The high-level radioactive waste canisters degrade faster than the spent nuclear fuel canisters because they are not as thick. The analysis evaluated three corrosion mechanisms—general corrosion, pitting corrosion, and crevice corrosion (DIRS 104597-Battelle 1998, Appendix A). Of the three, crevice corrosion would be the dominant failure mechanism for the regions analyzed. Corrosion rates and penetration times vary among the different regions of the country. The analysis calculated regional penetration times from the time at which it assumed that precipitation first would come in contact with the stainless steel. Table K-1 lists the results.

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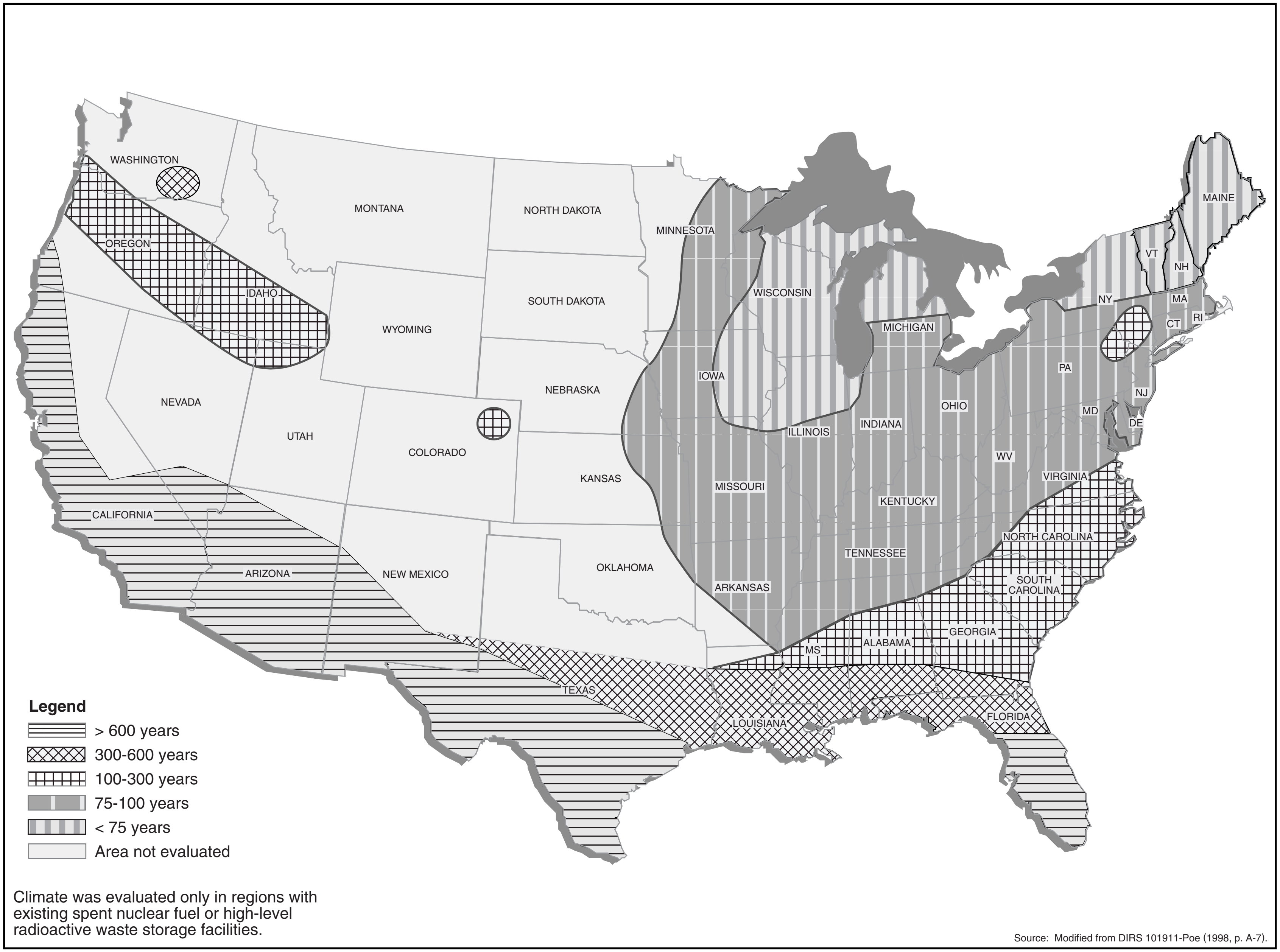


Figure K-3. Failure times for above-ground concrete storage modules.

Table K-1. Time (years) after the assumed loss of effective institutional control at which first failures would occur and radioactive materials could reach the accessible environment.

Material	Region	Storage facility	Weather[a] protection lost	Canister[b] breached (initial material release)
Commercial spent nuclear fuel	1	Surface	100	1,400
	2	Surface	700	1,500
	3	Surface	170	1,100
	4	Surface	750	1,600
	5	Surface	3,500	5,400
DOE spent nuclear fuel	2	Surface	700	1,400
	5	Surface	50	1,400
	5	Below grade	50	800
High-level radioactive waste	1	Surface	100	1,200
	2	Below grade	50	500
	5	Below grade	50	700

a. Source: Adapted from DIRS 101911-Poe (1998, Appendix A).
b. Source: DIRS 104597-Battelle (1998, data files, all); spent nuclear fuel dry storage or high-level radioactive waste canister.

K.2.1.3 Infiltration

The third process analyzes infiltration of water to the spent nuclear fuel and high-level radioactive waste. The amount of water in contact with these materials would be directly related to the size of the dry storage canister footprint and the mean (average) annual precipitation at each storage site. The rate of precipitation varies throughout the United States from extremely low (less than 25 centimeters [10 inches] per year) in the arid portions of the west to high (more than 150 centimeters [60 inches] per year) along the Gulf Coast in the southeast (Table K-2, Figure K-4). Local precipitation rates were used to determine the amount of water available that could cause dry storage canister and cladding failure, and spent nuclear fuel and high-level radioactive waste material dissolution.

Table K-2. Average regional precipitation.[a]

Region	Annual precipitation (centimeters)[b]	Percent of days with precipitation
1	110	30
2	130	29
3	80	33
4	110	31
5	30	24

a. Source: Adapted from DIRS 101911-Poe (1998, Appendix A, pp. A-13 to A-16).
b. To convert centimeters to inches, multiply by 0.3937.

K.2.1.4 Cladding

The fourth process analyzed was failure of the cladding, which is a protective barrier, usually metal (aluminum, zirconium alloy, stainless steel, nickel-chromium, Hastalloy, tantalum, or graphite), surrounding the spent nuclear fuel material to contain radioactive materials. For spent nuclear fuel, cladding is the last engineered barrier to be breached before the radioactive material can begin to be released to the environment.

K.2.1.4.1 *Commercial Spent Nuclear Fuel Cladding*

The principal cladding material used on commercial spent nuclear fuel is zirconium alloy. About 1.2 percent (of MTHM) of commercial spent nuclear fuel is stainless-steel clad (Appendix A,

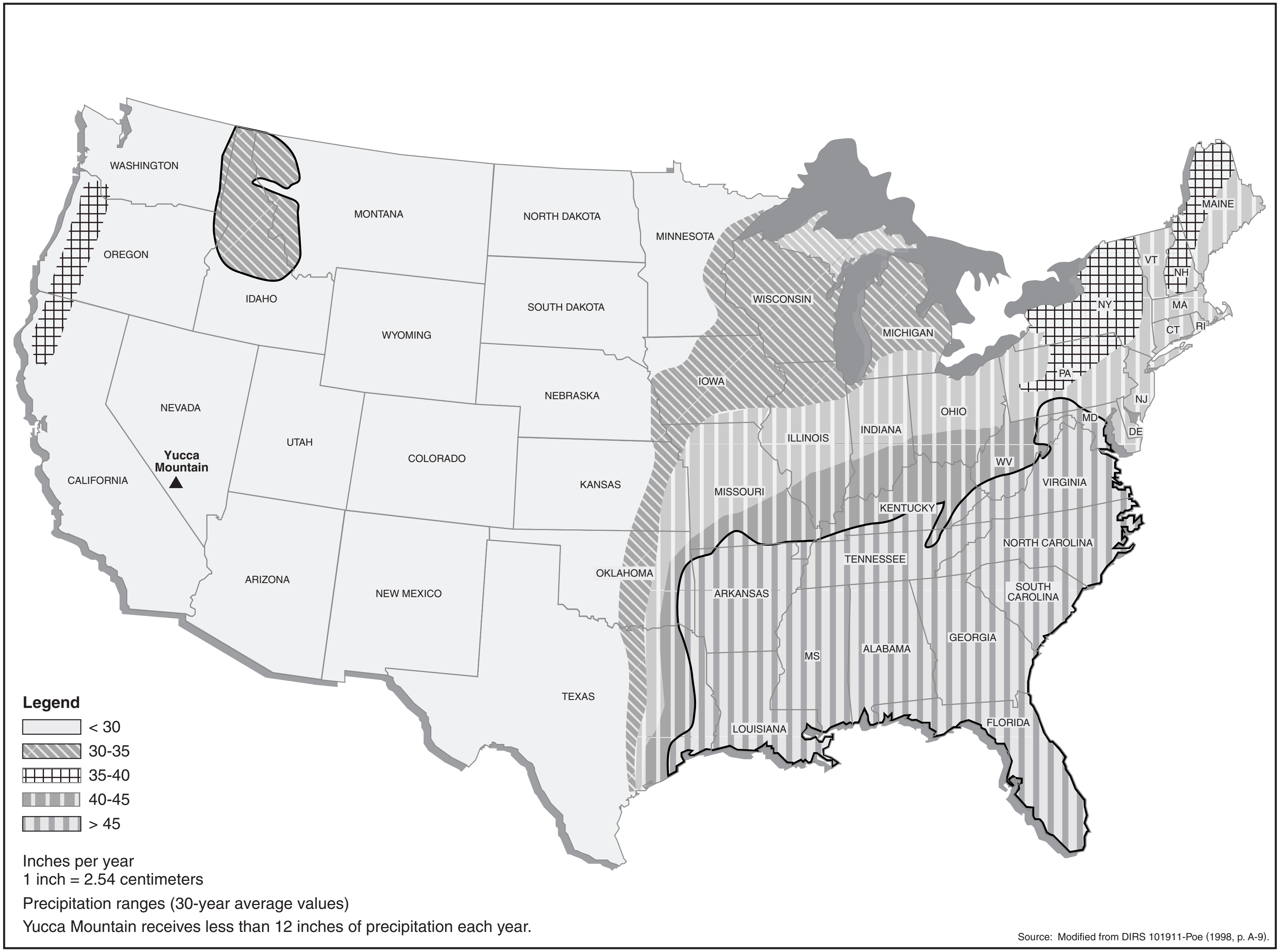
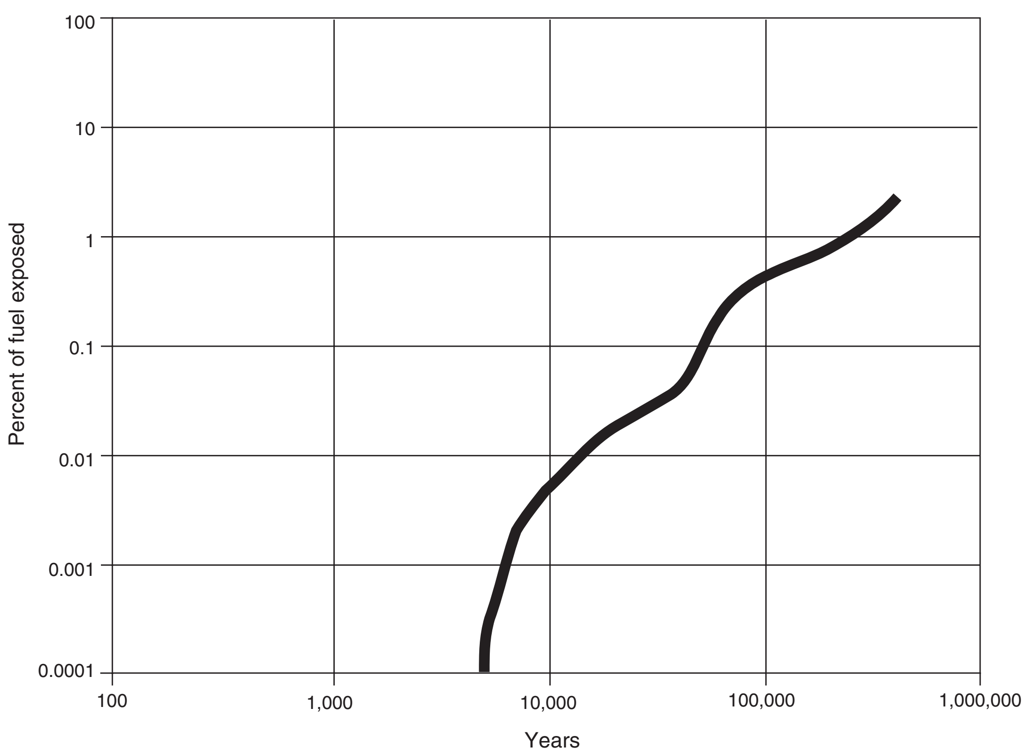


Figure K-4. Precipitation ranges for regions with existing spent nuclear fuel and high-level radioactive waste storage facilities.

Section A.2.1.5.3). To be consistent with the TSPA-VA, this analysis evaluated two cladding failure mechanisms: (1) so-called *juvenile failures* (failures existing at the start of the analysis period), and (2) *new failures* (failures that occur during the analysis period due to conditions in the storage container). The analysis assumed that juvenile failures existed in 0.1 percent of the zirconium alloy-clad spent nuclear fuel and in all of the stainless-steel-clad fuel at the beginning of the analysis period, and that after failure the cladding would offer no further protection to the radioactive material [this is consistent with the Viability Assessment assumption (DIRS 101779-DOE 1998, Volume 3, p. 3-97)].

Figure K-5 shows new failures (expressed as percent of commercial spent nuclear fuel over time) of zirconium alloy cladding, which were modeled using the median value assumed in the TSPA-VA cladding abstraction (DIRS 100362-CRWMS M&O 1998, pp. 6-19 to 6-54) for zirconium alloy corrosion. The Viability Assessment (DIRS 101779-DOE 1998, Volume 3, all) defines this information as a "fractional multiplier," which is calculated from the fraction of the failed fuel pin surface area. In the No-Action analysis, this corrosion is assumed to commence when weather protection afforded by the waste package is lost and the cladding is exposed to environmental precipitation. The TSPA-VA also considers cladding failure from creep strain, delayed hydride cracking, and mechanical failure from rock falls. These additional mechanisms normally occur after the 10,000-year analysis period and are therefore not considered in the No-Action analysis. As shown in Figure K-5, during the 10,000-year analysis period, less than 0.01 percent of the zirconium alloy-clad spent nuclear fuel would be expected to fail. If the upper limit curve from Figure 4 of the TSPA-VA cladding abstraction (DIRS 100362-CRWMS M&O 1998, pp. 6-19 to 6-54) was used, the value could be as high as 0.5 percent of the zirconium alloy-clad spent nuclear fuel. The lower limit value from the TSPA-VA cladding abstraction curve would be much less than 0.001 percent.



Source: Adapted from DIRS 100362-CRWMS M&O (1998, Figure 6-5).

Figure K-5. Percent of commercial spent nuclear fuel exposed over time due to new failures.

K.2.1.4.2 *DOE Spent Nuclear Fuel Cladding*

The composition and cladding materials of DOE spent nuclear fuel vary widely. The cladding assumption for the surrogate material used in this analysis is identical (no cladding credit) to the assumption used in the TSPA-VA analysis (see Section K.4.3.1 for the discussion of uncertainty in relation to cladding).

K.2.1.5 Dissolution of Spent Nuclear Fuel and High-Level Radioactive Waste

The fifth process analyzed was the dissolution of the spent nuclear fuel and high-level radioactive waste. The rate of release of radionuclides from these materials would be related directly to the amount of surface area exposed to moisture, the quantity and chemistry of available water, and temperature. The TSPA-VA process model, modified to reflect surface environmental conditions (temperature, relative humidity, etc.), was used to estimate release rates from the exposed spent nuclear fuel and high-level radioactive waste. The model and application to surface conditions is described in detail in Battelle (DIRS 104597-Battelle 1998, pp. 2.9 to 2.11).

K.2.1.5.1 *Commercial Spent Nuclear Fuel Dissolution*

Consistent with the repository impact analysis, this analysis estimated that new zirconium alloy failures would begin late in the 10,000-year period (see Figure K-5). As discussed in Section K.2.1.4.1, only 0.01 percent of the zirconium alloy-clad spent nuclear fuel would be likely to fail during the 10,000-year analysis period. Therefore, most of the exposed material considered in this analysis would result from juvenile failures of zirconium alloy- and stainless-steel-clad spent nuclear fuel.

K.2.1.5.2 *DOE Spent Nuclear Fuel Dissolution*

The analysis assumed that DOE spent nuclear fuel would be a metallic uranium fuel with zirconium alloy cladding (a representative or surrogate fuel that consisted primarily of N-Reactor fuel). Consistent with the repository input analysis, the No-Action Scenario 2 analysis takes no credit for the cladding. The analysis used the TSPA-VA model for metallic uranium fuel, modified for surface environmental conditions, to predict releases of the DOE spent nuclear fuel.

K.2.1.5.3 *High-Level Radioactive Waste Dissolution*

Most high-level radioactive waste would be stored in below-grade concrete vaults. As discussed in Section K.2.1.1, these vaults would be exposed to precipitation as soon as weather protection was lost (the model assumed this would occur 50 years after loss of institutional control). After the loss of weather protection and failure of the stainless-steel canisters, the high-level radioactive waste would be exposed to precipitation. The environment in the underground vault would be humid and deterioration would occur. Thus, the material would be exposed to either standing water or humid conditions in the degrading vaults after the canister failed. The borosilicate glass deterioration model used in this analysis was the same as the TSPA-VA model modified to reflect surface conditions (temperature and precipitation chemistry).

K.2.1.6 Regionalization of Sites for Analysis

The climate of the contiguous United States varies considerably across the country. The release rate of the radionuclide inventory would depend primarily on the interactions between environmental conditions (rainfall, freeze-thaw cycles) and engineered barriers. To simplify the analysis, DOE divided the country into five regions (see Figure K-2) (DIRS 101911-Poe 1998, p. 2).

The analysis assumed that a single hypothetical site in each region would store all the spent nuclear fuel and high-level radioactive waste existing in that region. Such a site does not exist but is a mathematical construct for analytical purposes. To ensure that the calculated results for the regional analyses reflect appropriate inventory, facility and material degradation, and radionuclide transport, the spent nuclear fuel and high-level radioactive waste inventories, engineered barriers, and environmental conditions for the hypothetical sites were developed from data for each of the existing sites in the given region. Weighting criteria to account for the amount and types of spent nuclear fuel and high-level radioactive waste at each site were used in the development of the environmental data for the regional site, such that the results of the analyses for the hypothetical site were representative of the sum of the results of each actual site if they had been modeled independently (DIRS 101911-Poe 1998, p. 1). If there are no storage facilities in a particular area of the country, the environmental parameters of that area were not evaluated.

Table K-3 lists the Proposed Action and Module 1 quantities of commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste in each of the five regions. The values in Table K-1 are the calculated results of failures of the various components of the protective engineered barriers and release of radioactive material in each region.

Table K-3. Proposed Action and Module 1 quantities of spent nuclear fuel (metric tons of heavy metal) and canisters of high-level radioactive waste in each geographic region.[a,b]

	Commercial spent nuclear fuel[c]								
	Region total[d]		With juvenile cladding failure		Stainless-steel cladding	DOE spent nuclear fuel[e]		High-level radioactive waste[f]	
Region	Proposed Action (MTHM)	Module 1 (MTHM)	Proposed Action (MTHM)	Module 1 (MTHM)	Proposed Action and Module 1 (MTHM)	Proposed Action (MTHM)	Module 1 (MTHM)	Proposed Action[g] (canisters)	Module 1[g] (canisters)
1	16,800	27,000	16	27	410			300	300
2	18,900	31,800	19	32	0	30	45	6,000	6,200
3	15,000	22,900	15	23	170				
4	7,200	14,100	7	14	0				
5	5,400	9,600	5	9	140	2,300	2,455	2,000	15,500
Totals	***63,000***	***105,000***	***62***	***105***	***720***	***2,300***	***2,500***	***8,300***	***22,000***

a. Source: Appendix A.
b. Totals might differ from sums due to rounding.
c. All analyzed as stored on surface as shown on Chapter 2, Figures 2-32, 2-33, and 2-34.
d. Includes plutonium in mixed-oxide spent nuclear fuel, which is assumed to behave like other commercial spent nuclear fuel.
e. A representative or surrogate fuel that consisted primarily of N-reactor fuel.
f. Includes immobilized plutonium.
g. Historically, a canister of high-level radioactive waste has been assumed to be equivalent to about 0.5 MTHM (see Appendix A, Section A.2.3.1).

K.2.2 RADIONUCLIDE RELEASE

The sixth and final step in the process is the release of radioactive materials to the environment. The anticipated release rates (fluxes) were estimated in terms of grams per 70-year period (typical human life expectancy in the United States) of uranium dioxide, uranium metal, or borosilicate glass for commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste, respectively. To assess potential lifetime impacts on human receptors, the amount of fission products and transuranics associated with gram quantities of uranium dioxide, uranium metal, and borosilicate glass were calculated for approximately 140 consecutive 70-year average human lifetimes to determine releases from the 10,000-year analysis period. Weighting criteria were used to ensure appropriate contributions by the different types of spent nuclear fuel and the high-level radioactive waste in each region, as appropriate.

The result was a single release rate for each region that accounted for the different materials (uranium dioxide, uranium metal, and borosilicate glass).

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The radionuclide distributions in the spent nuclear fuel and high-level radioactive waste (Appendix A) were used for these analyses. These were expressed as radionuclide-specific curies for storage packages (assembly or canister). The curies per storage package were converted to curies per gram of uranium dioxide, uranium metal, or borosilicate glass (as described above for each spent nuclear fuel and high-level radioactive waste material). This radionuclide distribution was multiplied by release flux (curies of spent nuclear fuel and high-level radioactive waste material per 70-year period) after being corrected for decay and the ingrowth of decay products for various times after disposal. These corrections were determined using the ORIGEN computer program (DIRS 147923-RSIC 1991, all) for each of the approximately 140 consecutive 70-year human lifetimes to determine the release over the 10,000-year period. The results of the ORIGEN runs were used as input to the environmental transport program.

DEFINITIONS

Fission products: Radioactive or non-radioactive atoms that are produced by the fission (splitting) of heavy atoms, such as uranium.

Transuranics: Radioactive elements, heavier than uranium, that are produced in a nuclear reactor when uranium atoms absorb neutrons rather than splitting. Examples of transuranics include plutonium, americium, and neptunium.

Curie: The basic unit of radioactivity. It is equal to the quantity of any radionuclide in which 37 billion atoms are decaying per second.

Specific activity: An expression of the number of curies of activity per gram of a given radionuclide. It is dependent on the half life and molecular weight of the nuclide.

In addition to the isotopes identified in the repository inventory specified in Appendix A, the No-Action Scenario 2 analysis considered 167 other isotopes in the light-water reactor radiological database (DIRS 102588-DOE 1992, p. 1.1-1). Of the 220 isotopes evaluated, six would contribute more than 99.5 percent of the total dose. Table K-4 lists these six isotopes along with technetium-99, which individually would contribute less than 0.003 percent of the total dose. Plutonium-239 and -240 would contribute more than 96 percent of the radiological impacts during the 10,000-year analysis period because of their very large dose conversion factors. Americium-241 and -243 would be minor contributors to the dose. Neptunium-237 and technetium-99 were of tertiary importance (Table K-4).

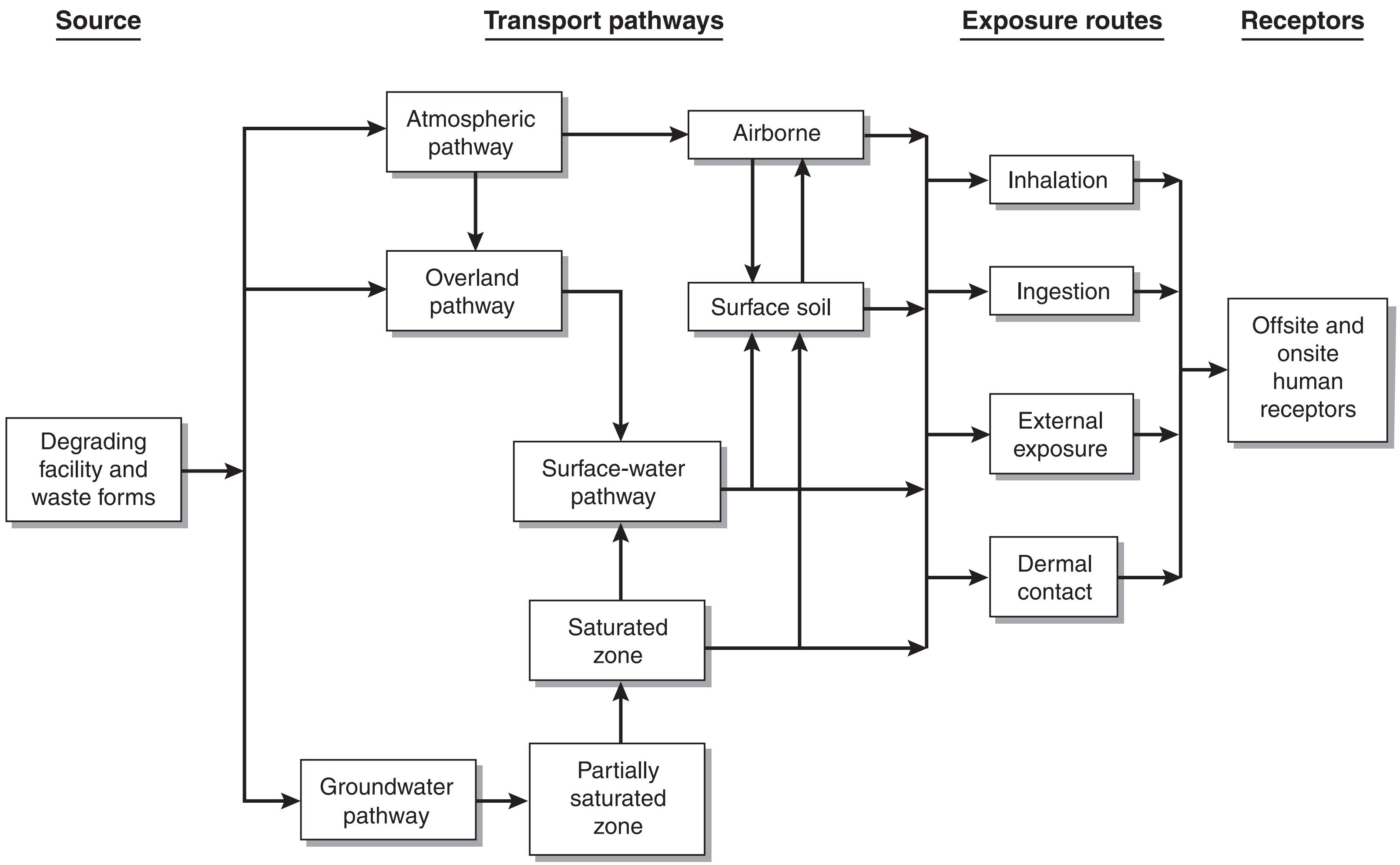
Table K-4. Radionuclides and relative contributions over 10,000 years to Scenario 2 impacts.[a]

Isotope	Percent of total dose
Americium-241	3.2
Americium-243	0.86
Neptunium-237	0.29
Plutonium-238	0.2
Plutonium-239	49.0
Plutonium-240	47.0
Technetium-99	< 0.003

a. Source: DIRS 101935-Toblin (1999, p. 6).

K.2.3 ENVIRONMENTAL TRANSPORT OF RADIOACTIVE MATERIALS

Radioactive materials in degraded spent nuclear fuel and high-level radioactive waste could be transported to the environment surrounding each storage facility by three pathways: groundwater, surface-water runoff, and atmosphere. Figure K-6 shows the potential exposure pathways. The analysisassumed that existing local climates would persist throughout the time of exposure of the spent nuclear fuel and high-level radioactive waste to the environment. The assumed configuration for the



Source: Adapted from DIRS 101533-Buck et al. (1995, all).

Figure K-6. Potential exposure pathways associated with degradation of spent nuclear fuel and high-level radioactive waste.

degraded storage facilities would have debris covering the radioactive material, which would remain inside the dry storage canisters. While the dry storage canisters could fail sufficiently to permit water to enter, they probably would retain their structural characteristics, thereby minimizing the dispersion of radioactive particulate material to the atmosphere (DIRS 147905-Mishima 1998, p. 4). Based on this analysis, the airborne particulate pathway generally would not be an important source of human exposure. The assumption is that after radionuclides dissolved in the precipitation they would reach the environment either through groundwater or surface-water transport.

The analysis performed environmental fate and transport pathway modeling using the Multimedia Environmental Pollutant Assessment System program (DIRS 101533-Buck et al. 1995, all). The Multimedia Environmental Pollutant Assessment System is an integrated system of analytical, semianalytical, and empirically based mathematical models that simulate the transport and fate of radioactive materials through various environmental media and calculate concentrations, doses, and health effects at designated receptor locations.

The Multimedia Environmental Pollutant Assessment System was originally developed by Pacific Northwest National Laboratory to enable DOE to prioritize the investigation and remediation of the Department's hazardous, radioactive, and mixed waste sites in a scientific and objective manner based on readily available site information. The Multimedia Environmental Pollutant Assessment System has evolved into a widely accepted (by Federal and international agencies) computational tool for calculating the magnitude of environmental concentrations and public health impacts caused by releases of radioactive material from various sources.

The following sections discuss the assumptions and methods used to determine radioactive material transport for groundwater and surface-water pathways. Environmental parameters defined for input to the Multimedia Environmental Pollutant Assessment System program were collected from various sources for specific sites (DIRS 101925-Sinkowski 1998, p. 2) and regionalized parameters were developed (DIRS 101912-Poe and Wise 1998, all). The analysis used long-term averages to represent environmental conditions, and assumed that these parameters would remain constant over the 10,000-year analysis period. The following sections discuss the method for each pathway.

K.2.3.1 Groundwater Transport

Precipitation falling on degrading spent nuclear fuel and high-level radioactive waste material would form a radioactive solution (leachate) that could migrate through the vadose zone (the unsaturated upper layer of soil) to the underlying water table, which would dilute, disperse, and transport the material downgradient through the local aquifer system. As a result, there is a potential for human exposure through the groundwater pathway to downgradient well users and to populations along surface-water bodies where groundwater feeds into surface water.

The groundwater component of the radioactive material fluxes (infiltration) averaged over 70-year (lifetime) increments was entered in the Multimedia Environmental Pollutant Assessment System program. The infiltration would carry the contaminated leachate down through the vadose zone to the saturated zone (aquifer). The contaminants would be diluted and dispersed as they traveled through the aquifer. Radioactive material retardation would occur in both the unsaturated (above the water table) and saturated (below the water table) zones. A distribution adsorption (that is, surface retention) coefficient, K_d, (the amount of material adsorbed to soil particles relative to that in the water) modeled this retardation (DIRS 101935-Toblin 1999, p. 2). This coefficient is radioactive material-specific and varies for each material based on such factors as soil pH and clay content.

Table K-5 lists the adsorption coefficients, K_d, for the elements explicitly modeled for groundwater transport. The coefficients are expressed as a function of the clay content of the soil through which the

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Table K-5. Multimedia Environmental Pollutant Assessment System default elemental equilibrium adsorption coefficients (K_d; milliliters per gram) for soil pH between 5 and 9.[a]

Element	Clay content by weight		
	< 10 percent	10 to 30 percent	≥ 30 percent
Actinium	228	538	4,600
Americium	82	200	1,000
Californium	0	0	0
Carbon	0	0	0
Cesium	51	249	270
Chlorine	0	0	0
Cobalt	2	9	200
Curium	82	200	1,000
Iodine	0	0	0
Krypton	0	0	0
Lead	234	597	1,830
Neptunium	3	3	3
Nickel	12	59	650
Niobium	50	100	100
Palladium	0	4	40
Plutonium	10	100	250
Protactinium	0	50	500
Radium	24	100	124
Ruthenium	274	351	690
Samarium	228	538	4,600
Selenium	6	15	15
Strontium	24	100	124
Technetium	3	20	20
Thorium	100	500	2,700
Tin	5	10	10
Tritium	0	0	0
Uranium	0	50	500
Zirconium	50	500	1,000

a. Source: DIRS 101935-Toblin (1999, p. 2).

elements are being transported; the analyses assumed a soil pH between 5 and 9. Note that the K_d values of all isotopes of a given element (for example, plutonium-238, -239, and -240) are the same, because adsorption is a chemical rather than nuclear process.

The time required to traverse the groundwater was determined for each radionuclide. Tables K-6 and K-7 list the range of nuclide groundwater transport times, from source to receptor, for each of the five regions. Times are listed for the important nuclides (see Table K-4). The analysis assumed that the vadose/aquifer flow fields were steady-state, so that the nuclide travel times at a particular site would be constant over the 10,000-year analysis period, although the nuclide release rates were not. Table K-6 lists parameters describing the total (over the analysis period) and maximum nuclide release rates for the same important nuclides. Region 5, dominated by two large DOE sites, is seen to result in the largest nuclide releases of all of the regions.

Table K-7 also lists the number of water systems and people that would obtain water from the affected waterways. Many of these people would be subject to impacts from more than one site because they would obtain their water from affected waterways downstream from multiple sites.

When the groundwater reached the point where it outcropped to surface water, radioactive material transport would be subject to further dilution and dispersion. For most of the regions analyzed, the

Table K-6. Regional source terms and environmental transport data for important isotopes used for collective drinking water radiological impact analysis.[a]

Parameter	Plutonium-239/240	Plutonium-238	Americium-241	Americium-243	Neptunium-237	Technetium-99
Nuclide released in 10,000 years (curies)						
Region 1	4,200	20	660	115	8.9	98
Region 2	17,000	97	1,500	240	32	1,200
Region 3	130,000	660	31,000	3,300	260	2,600
Region 4	4,300	17	450	110	9.0	89
Region 5	570,000	180	42,000	1,700	720	6,500
Maximum annual nuclide release (curies per year)						
Region 1	19	0.020	1.2	0.053	0.0031	0.034
Region 2	53	0.035	2.2	0.11	0.0083	0.19
Region 3	60	0.71	56	1.6	0.092	1.0
Region 4	0.20	0.016	0.78	0.054	0.0034	0.035
Region 5	140	0.22	66	0.47	0.14	1.4
Years (from 2016) of maximum annual nuclide release						
Region 1	1,435	1,435	1,435	1,435	1,435	1,435
Region 2	1,575	1,575	1,575	1,575	1,575	1,575
Region 3	1,155	1,155	1,155	1,155	1,155	1,155
Region 4	1,715	1,715	1,715	1,715	1,715	1,715
Region 5	875	875	875	875	875	875
Nuclide reaching receptors in 10,000 year (curies)						
Region 1	3,600	11	130	43	8.8	95
Region 2	13,000	10	1.4	39	31	1,100
Region 3	110,000	250	380	510	250	2,500
Region 4	2,000	3.6	0.66	24	6.0	59
Region 5	180,000	2.6	0.020	1.2	630	5,600
Nuclide transport time[b] (years)						
Region 1	10-5,500	10-5,500	10-45,000	10-45,000	10-1,700	10-1,700
Region 2	460-9,000	460-9,000	2,000-36,000	2,000-36,000	43-860	140-1,500
Region 3	65-45,000	65-45,000	410-260,000	410-260,000	31-9,800	31-9,800
Region 4	850-520,000	850-520,000	3,000-1,000,000	3,000-1,000,000	59-16,000	130-100,000
Region 5	1,400-26,000	1,400-26,000	2,700-220,000	2,700-220,000	44-8,000	280-8,000

a. Source: DIRS 101935-Toblin (1999, p. 4).
b. Time from source to receptor.

Table K-7. Transport and population data for drinking water pathway impact analysis.

Parameter	Region 1	Region 2	Region 3	Region 4	Region 5
Groundwater flow time (years)[a]	2.0 - 59	4.6 - 37	1.8 - 420	4.6 - 960	2.9 - 190
Number of people that would obtain domestic water supply from affected waterways (millions)[b]	6.7	5.3	13.1	5.3	0.16
Affected drinking water systems[c]	112	147	137	64	23

a. From source to outcrop; Source: Adapted from DIRS 101852-Jenkins (1998, Table 2).
b. Source: DIRS 101911-Poe (1998, p. 12).
c. Source: Adapted from DIRS 101925-Sinkowski (1998, all).

distance between the storage location and the downgradient surface-water body would be inside the site boundary; therefore, offsite wells generally would not be affected. However, the analysis calculated groundwater concentrations for hypothetical onsite and offsite receptors. The Multimedia Environmental Pollutant Assessment System program calculated groundwater and surface-water concentrations at each receptor location for consecutive 70-year lifetimes in the 10,000-year analysis period.

The parameters necessary for the spent nuclear fuel and high-level radioactive waste storage sites for the Multimedia Environmental Pollutant Assessment System were defined. Pertinent hydrologic and hydrogeologic information was derived from the site-specific Updated Final Safety Analysis Reports for commercial nuclear sites and site-specific data provided by the various DOE sites (DIRS 101852-Jenkins 1998, p. 1).

Table K-8 lists the range (over the individual sites) in each region of the important hydrogeologic parameters that would affect the transport of the radionuclides through the groundwater. These parameters form the basis for the nuclide transport times listed in Table K-7.

Table K-8. Multimedia Environmental Pollutant Assessment System regional groundwater input parameters.[a]

Parameter	Region 1	Region 2	Region 3	Region 4	Region 5
Vadose zone					
Contaminated liquid infiltration rate (vertical Darcy velocity) (feet per year)[b]	3.1 - 3.5	4.4	2.7 - 3.1	2.7 - 4.4	0.88 - 3.1
Clay content (percent)	0 - 15	1 - 47	1 - 47	3 - 15	0 - 15
pH of pore water	5 - 9	5 - 9	5 - 9	5 - 9	5 - 9
Thickness (feet)	6 - 40	5 - 70	4 - 31	5 - 50	23 - 250
Bulk density (grams per cubic centimeter)	1.4 - 1.9	1.4 - 1.6	1.4 - 1.6	1.4 - 1.6	1.4 - 1.7
Total porosity (percent)	5 - 46	38 - 49	38 - 49	38 - 46	38 - 49
Field capacity (percent)	2.5 - 28	9 - 42	9 - 42	9 - 28	3 - 28
Saturated hydraulic conductivity (feet per year)	210 - 6,800	27 - 6,800	27 - 6,800	210 - 6,800	72 - 6,800
Aquifer					
Clay content (percent)	0 - 10	0 - 47	0 - 15	0 - 15	0 - 10
pH of pore water	5 - 9	5 - 9	5 - 9	5 - 9	5 - 9
Thickness (feet)	6 - 120	10 - 85	7 - 160	20 - 150	25 - 250
Bulk density (grams per cubic centimeter)	1.6 - 2.1	1.4 - 2.0	1.5 - 1.7	1.4 - 1.7	1.5 - 1.9
Total porosity (percent)	5 - 44	5 - 49	5 - 46	5 - 46	23 - 44
Effective porosity (percent)	2.9 - 22	2.9 - 28	2.9 - 25	22 - 27	13 - 25
Saturated hydraulic conductivity (feet per year)	210 - 6,800	27 - 6,800	27 - 6,800	210 - 6,800	72 - 6,800
Darcy velocity (feet per year)	6.8 - 1,400	12 - 170	3.9 - 430	0.58 - 270	33 - 560
Travel distance (feet)	1,900 - 5,600	2,000 - 4,700	1,900 - 23,000	1,600 - 12,000	1,900 - 37,000

a. Source: Adapted from DIRS 101852-Jenkins (1998, Table 2).
b. Annual precipitation rate (through degraded structure).

A simplifying analytical assumption was that radioactive material transport would occur only through the shallowest aquifer beneath the site. Because this assumption limits the interchange of groundwater with underlying aquifers, less radioactive material dilution would occur, and groundwater pathway impacts could be slightly overestimated. However, because impacts from the groundwater pathway would be minor in comparison to surface-water pathways, the total estimated impacts would not be affected by this assumption.

K.2.3.2 Surface-Water Transport

The amount of leachate from degraded spent nuclear fuel and high-level radioactive waste in the surface-water pathway would depend on soil characteristics and the local climate. The Multimedia Environmental Pollutant Assessment System considers precipitation rates (Table K-2), soil infiltration, evapotranspiration, and erosion management practices to determine the amount of leachate that would run off rather than percolate into the soil. The contaminated runoff would travel overland and eventually enter nearby rivers and streams that would dilute it further.

To determine the impacts of the contaminated discharge to surface water on the downstream populations using that water (affected populations), DOE calculated the surface water flow rate and the release rate of contaminants (as curies per year) contributed by each storage location draining to the surface water. Using these values, DOE determined surface-water radionuclide concentrations for each receptor location. DOE applied these concentrations to the respective affected populations to estimate impacts for each region.

K.2.3.3 Atmospheric Transport

If degraded spent nuclear fuel or high-level radioactive waste was exposed to the environment, small particles could become suspended in the air and transported by wind. The Multimedia Environmental Pollutant Assessment System methodology includes formulations for radioactive material (particulate) suspension by wind, vehicular traffic, and other physical disturbances of the ground surface. The impacts from the atmospheric pathways would be small in comparison to surface-water pathways because the cover provided by the degraded structures and the relatively large particle size and density of the materials (see Section K.2.3) would preclude suspension by wind. Therefore, impacts from the transport of radioactive particulate materials were not included in the analysis.

K.2.4 HUMAN EXPOSURE AND DOSE CALCULATIONS

This section describes methods used in the No-Action Scenario 2 analysis to estimate dose rates and potential impacts to individuals and population groups from exposures to radionuclide contaminants in groundwater and surface water and in the atmosphere. As discussed above, these contaminated environmental media would result from the degradation of storage facilities (Sections K.2.1.1), corroding dry storage canisters (Section K.2.1.2), cladding failure (Section K.2.1.4), spent nuclear fuel and high-level radioactive waste dissolution (Section K.2.1.5), leachate percolation and groundwater transport (Section K.2.3.1), surface-water runoff (Section K.2.3.2), and atmospheric suspension and transport (Section K.2.3.3).

For Scenario 1 and the first 100 years of Scenario 2, the presence of effective institutional control would ensure that radiological releases to the environment and radiation doses to workers and the public remained within Federal limits and DOE Order requirements and were maintained as low as reasonably achievable. As a result, impacts to members of the public would be very small. Potential radiological human health impacts that could occur would be due primarily to occupational radiation exposure of onsite workers. The analysts estimated these impacts based on actual operational data from commercial nuclear powerplant sites (DIRS 101898-NRC 1991, pp. 22 to 25) and projected these impacts for the 100- and 10,000-year analysis periods for Scenario 1.

For Scenario 2, impacts to onsite workers and the public during institutional control (approximately 100 years) would be the same as those for Scenario 1. However, because the assumption for Scenario 2 is that there would be no effective institutional control after approximately 100 years, engineered barriers would begin to degrade and eventually would not prevent radioactive materials from the spent nuclear fuel and high-level radioactive waste from entering the environment. During the period of no effective institutional control, there would be no workers at the site. Thus, impacts were calculated only for the public.

For Scenario 2, the potential highest exposures and dose rates over a 70-year lifetime period were evaluated for individuals and exposed populations. In addition, the total integrated dose to the exposed population for the 10,000-year analysis period was estimated. Human exposure parameters (exposure times, ingestion and inhalation rates, agricultural activities, food consumption rates, etc.) were developed based on recommendations from Federal agencies (DIRS 101819-EPA 1988, pp. 113 to 131; DIRS 101820-EPA 1991, Attachment B; DIRS 100067-NRC 1977, pp. 1.109-1 to 1.109-2; DIRS 147925-

Shipers and Harlan 1989, all; DIRS 147915-NRC 1991, Chapter 6) and are reflected as Multimedia Environmental Pollutant Assessment System default values (DIRS 101533-Buck et al. 1995, Section 1.0). Other parameters chosen for this analysis are summarized in supporting documentation (DIRS 101925-Sinkowski 1998, all; DIRS 101935-Toblin 1999, all; DIRS 101936-Toblin 1999, all; DIRS 101937-Toblin 1998, all). Table K-9 lists the exposure and usage parameters for all of the pathways considered in the analysis (see Section K.3.1).

The Scenario 2 analysis evaluated long-term radiation doses and impacts to populations exposed through the surface-water and groundwater pathways. This analysis estimated population impacts only for the drinking water pathway using regionalized effective populations and surface-water dilution factors discussed in Section K.2.3.2. Other pathways were evaluated to determine their potential contribution in relation to drinking water doses. These analyses are discussed in Section K.3.1.

K.2.4.1 Gardener Impacts

To reasonably bound human health impacts resulting from human intrusion, two types of gardener were evaluated—the onsite gardener (10 meters [33 feet]) from the degrading storage facility) and the near-site gardener (5 kilometers [3 miles] from the degrading facility). The analysis had both of these hypothetical gardeners residing on the flow path for groundwater. The gardeners would obtain all their drinking water from contaminated groundwater, grow their subsistence gardens in contaminated soils, and irrigate them with the contaminated groundwater. The contaminated garden soils, suspended by the wind, would contaminate the surfaces of the vegetables consumed by the gardeners. The hypothetical onsite gardener would be the maximally exposed individual.

HUMAN INTRUSION

Spent nuclear fuel and high-level radioactive waste in surface or below-grade storage facilities would be readily accessible in the absence of institutional control. For this reason, DOE anticipates that both planned and inadvertent intrusions could occur. An example of the former would be the scavenger who searches through the area seeking articles of value; an example of the latter would be the farmer who settles on the site and grows agricultural crops with no knowledge of the storage structure beneath the soil. Intrusions into contaminated areas also could occur through activities such as building excavations, road construction, and pipeline or utility replacement.

Under the conditions of Scenario 2, intruders could receive external exposures from stored spent nuclear fuel and high-level radioactive waste that would grossly exceed current regulatory limits and, in some cases, could be sufficiently high to cause prompt fatalities. In addition, long-term and repeated intrusions, such as those caused by residential construction or agricultural activities near storage sites, could result in long-term chronic exposures that could produce increased numbers of latent cancer fatalities. These intrusions could also result in the spread of contamination to remote locations, which could increase the total number of individuals potentially exposed.

Calculations were performed using transport models described by DIRS 101533-Buck et al. (1995, all) for gardeners in each of the five analysis regions using regionalized source terms and environmental parameters. Therefore, calculated impacts to the regional gardener (maximally exposed individual) would not represent the highest impacts possible from a single site in a given region, but rather would reflect an average impact for the region. Details of the analysis are provided in DIRS 101937-Toblin (1998, all). The regional hydrogeologic parameters listed in Table K-10, together with transient nuclide release rates (the maximum of which is indicated in the table), were used to determine the radiological impacts to the regional gardener as a result of groundwater transport. The regional parameters were based on a curie-weighting of the individual site parameters for plutonium and americium. The exposure

Table K-9. Multimedia Environmental Pollutant Assessment System human exposure input parameters for determination of all pathways radiological impacts sensitivity analysis (page 1 of 2).[a]

Water source[b]	Surface water
Domestic water supply treatment[c]	Yes
Fraction of plutonium removed by water treatment[d]	0.3
Drinking water rate (liters per day per person)[e]	2
Irrigation rate (liters per square meter per month)[f]	100
Leafy vegetable consumption rate (kilograms per day per person)[g]	0.021
Other vegetable consumption rate (kilograms per day per person)	0.13
Meat consumption rate (kilograms per day per person)	0.065
Milk consumption rate (kilograms per day per person)	0.075
Finfish consumption rate (kilograms per day per person)	0.0065
Shellfish consumption rate (kilograms per day per person)	0.0027
Shoreline contact (hours per day per person)	0.033
Americium ingestion dose conversion factor (rem per picocurie)[h]	3.6×10^{-6}
Americium finfish bioaccumulation factor	250
Americium shellfish bioaccumulation factor	1,000
Americium meat transfer factor (days per kilogram)	3.5×10^{-6}
Americium milk transfer factor (days per liter)	4.0×10^{-7}
Neptunium ingestion dose conversion factor (rem per picocurie)	4.4×10^{-6}
Neptunium finfish bioaccumulation factor	250
Neptunium shellfish bioaccumulation factor	400
Neptunium meat transfer factor (days per kilogram)	5.5×10^{-5}
Neptunium milk transfer factor (days per liter)	5.0×10^{-6}
Technetium ingestion dose conversion factor (rem per picocurie)	1.5×10^{-9}
Technetium finfish bioaccumulation factor	15
Technetium shellfish bioaccumulation factor	5
Technetium meat transfer factor (days per kilogram)	8.5×10^{-3}
Technetium milk transfer factor (days per liter)	1.2×10^{-2}
Plutonium ingestion dose conversion factor (rem per picocurie)[i]	3.5×10^{-6}
Plutonium finfish bioaccumulation factor	250
Plutonium shellfish bioaccumulation factor	100
Plutonium meat transfer factor (days per kilogram)	5.0×10^{-7}
Plutonium milk transfer factor (days per liter)	1×10^{-7}
Yield of leafy vegetables [kilograms (wet) per square meter]	2.0
Yield of vegetables [kilograms (wet) per square meter]	2.0
Yield of meat feed crops [kilograms (wet) per square meter]	0.7
Yield of milk animal feed crops [kilograms (wet) per square meter]	0.7
Meat animal intake rate for feed (liters per day)	68
Milk animal intake rate for feed (liters per day)	55
Meat animal intake rate for water (liters per day)	50
Milk animal intake rate for water (liters per day)	60
Agricultural areal soil density (kilograms per square meter)	240
Retention fraction of activity on plants	0.25
Translocation factor for leafy vegetables	1.0
Translocation factor for other vegetables	0.1
Translocation factor for meat animal	0.1
Translocation factor for milk animal	1.0
Fraction of meat feed contaminated	1.0
Fraction of milk feed contaminated	1.0
Fraction of meat water contaminated	1.0
Fraction of milk water contaminated	1.0
Meat animal soil intake rate (kilograms per day)	0.5

Table K-9. Multimedia Environmental Pollutant Assessment System human exposure input parameters for determination of all pathways radiological impacts sensitivity analysis (page 2 of 2).[a]

Water source[b]	Surface water
Milk animal soil intake rate (kilograms per day)	0.5
Leafy vegetable growing period (days)	60
Other vegetable growing period (days)	60
Beef animal feed growing period (days)	30
Milk animal feed growing period (days)	30
Water intake rate while showering (liters per hour)	0.06
Duration of shower exposure (hours per shower)	0.167
Shower frequency (per day)	1.0
Thickness of shoreline sediment (meters)	0.04
Density of shoreline sediments (grams per cubic meter)	1.5
Shore width factor for shoreline external exposure	0.2

a. Source: DIRS 101936-Toblin (1999, pp. 4 and 5).
b. Groundwater for gardener.
c. No for gardener.
d. Zero for gardener.
e. To convert liters to gallons, multiply by 0.26418.
f. To convert liters per square meter to gallons per square foot, multiply by 0.00025.
g. To covert kilograms to pounds, multiply by 2.2046.
h. Sediment ingestion = 0.1 grams per hour (0.000022 pound per hour) during contact.
i. For plutonium-239/240.

Table K-10. Multimedia Environmental Pollutant Assessment System groundwater transport input parameters for estimating radiological impacts to the onsite and near-site gardener.[a]

Parameter	Region 1	Region 2	Region 3	Region 4	Region 5
Vadose zone					
Contaminated liquid infiltration rate (vertical Darcy velocity) (feet per year)[b,c]	3.5	4.4	2.7	3.5	0.88
Clay content (percent)	1	10	12	11	2
pH of pore water	5 - 9	5 - 9	5 - 9	5 - 9	5-9
Thickness (feet)	11	44	7.1	43	180
Longitudinal dispersivity (feet)	0.11	0.44	0.071	0.43	1.8
Bulk density (grams per cubic meter)[d]	1.6	1.5	1.5	1.5	1.6
Total porosity (percent)	38	42	44	45	41
Field capacity (percent)	9.3	15	23	21	12
Saturated hydraulic conductivity (feet per year)	6,500	660	1,700	1,000	5,900
Aquifer					
Clay content (percent)	1.8	6.5	1.2	4.4	0.69
pH of pore water	5 - 9	5 - 9	5 - 9	5 - 9	5 - 9
Thickness (feet)	45	50	37	64	210
Bulk density (grams per cubic meter)	1.6	1.8	1.6	1.6	1.7
Total porosity (percent)	38	40	38	35	30
Effective porosity (percent)	22	23	22	20	17
Darcy velocity (feet per year)	340	62	69	51	300
Longitudinal dispersivity (feet)	f(x)[e]	f(x)	f(x)	f(x)	f(x)
Lateral dispersivity (feet)	f(x) ÷ 3	f(x) ÷ 3	f(x) ÷ 3	f(x) ÷ 3	f(x) ÷ 3
Vertical dispersivity (feet)	f(x) ÷ 400	f(x) ÷ 400	f(x) ÷ 400	f(x) ÷ 400	f(x) ÷ 400
Maximum annual plutonium-239 and -240 release (curies per year)	4.9	0.24	3.8	0.32	2.1
Years (from 2016) of maximum annual plutonium release	1,365	1,575	1,155	1,715	875

a. Source: DIRS 101937-Toblin (1998, p. 2-4).
b. Annual precipitation rate (through degraded structure).
c. To convert feet to meters, multiply by 0.3048.
d. To convert grams per cubic meter to pounds per cubic foot, multiply by 0.0000624.
e. $f(x) = 2.72 \times (\log_{10} 0.3048 \times x)^{2.414}$, where x = downgradient distance.

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parameters in Table K-9 describe the radionuclide exposure to the gardener where applicable (for example, exposure parameters related to the fish are not applicable to the gardener).

K.2.4.2 Direct Exposure

The analysis evaluated potential external radiation dose rates to the maximally exposed individual for a commercial independent spent fuel storage installation because this type of facility would provide the highest external exposures of all the facilities analyzed in this appendix. Maximum dose rates over the 10,000-year analysis period were evaluated for each region. The maximally exposed individual was assumed to be 10 meters (about 33 feet) from an array of concrete storage modules containing 1,000 MTHM of commercial spent nuclear fuel. The maximum dose rate varied between regions depending on how long the concrete shielding would remain intact (Table K-1).

The direct gamma radiation levels were calculated (DIRS 101556-Davis 1998, all). To ensure consistency between this analysis and the TSPA-VA, the same radionuclides were used for the design of the Yucca Mountain Repository surface facility shielding (DIRS 104603-CRWMS M&O 1995, Attachment 9.5). Radionuclide decay and radioactive decay product ingrowth over the 10,000-year analysis period were calculated using the ORIGEN computer program (DIRS 147923-RSIC 1991, all).

Neutron emissions were not included because worst-case impacts (death within a short period of exposure) would be the same with or without the neutron component.

K.2.5 ACCIDENT METHODOLOGY

Spent nuclear fuel and high-level radioactive waste stored in above-ground dry storage facilities would be protected initially by the robust surrounding structure (either metal or concrete) and by a steel storage container that contained the material. Normal storage facility operations would be primarily passive because the facilities would be designed for cooling via natural convection. DOE evaluated potential accident and criticality impacts for both Scenario 1 (institutional control for 10,000 years) and Scenario 2 (assumption of no effective institutional control after approximately 100 years with deterioration of the engineered barriers initially protecting the spent nuclear fuel or high-level radioactive waste).

For Scenario 1, human activities at each facility would include surveillance, inspection, maintenance, and equipment replacement when required. The facilities and the associated systems, which would be licensed by the Nuclear Regulatory Commission, would have certain required features. License requirements would include isolation of the stored material from the environment and its protection from severe accident conditions (10 CFR 50.34). The Nuclear Regulatory Commission requires an extensive safety analysis that considers the impacts of plausible accident-initiating events such as earthquakes, fires, high winds, and tornadoes. No plausible accident scenarios have been identified that result in the release of radioactive material from the storage facilities (DIRS 103449-PGE 1996, all; DIRS 103177-CP&L 1989, all). In addition, the license would specify that facility design requirements include features to provide protection from the impacts of severe natural events. These requirements and analyses must demonstrate that the facilities can withstand the most severe wind loading (tornado winds and tornado-generated missiles) and flooding from the Probable Maximum Hurricane with minimal release of radioactive material. This analysis assumed maintenance of these features indefinitely for the storage facilities.

DOE performed a scoping analysis to identify the kinds of events that could lead to releases of radioactive material to the environment prior to degradation of concrete storage modules and found none. The two events determined to be the most challenging to the integrity of the concrete storage modules would be the crash of an aircraft into the storage facility and a severe seismic event.

- DIRS 103711-Davis, Strenge, and Mishima (1998, all) evaluated the postulated aircraft crash and subsequent fire at a storage facility. The analysis showed that falling aircraft components produced by such an event would not penetrate the storage facility and that a subsequent fire would not result in a release of radioactive materials.

- For the seismic event, meaningful damage would be unlikely because storage facilities would be designed to withstand severe earthquakes. Even if such an event caused damage, no immediate release would occur because no mechanism has been identified that would cause meaningful fuel pellet damage to create respirable airborne particles. If this damage did not occur, the source term would be limited to gaseous fission products, carbon-14, and a very small amount of preexisting fuel pellet dust. Subsequent repairs to damaged facilities or concrete storage modules would preclude the long-term release of radionuclides.

Criticality events are not plausible for Scenario 1 because water, which is required for criticality, could not enter the dry storage canister. The water would have to penetrate several independent barriers, all of which would be maintained and replaced as necessary under Scenario 1.

Under Scenario 2, facilities would degrade over time and the structures would gradually deteriorate and lose their integrity. The analysis determined that two events, an aircraft crash and inadvertent criticality, would be likely to dominate the impacts from accidents, as described in the following paragraphs.

K.2.5.1 Aircraft Crash

DOE determined that an aircraft crash into a degraded concrete storage module would be a severe accident-initiating event that could occur at the storage sites. This event would provide the potential for the airborne dispersion of radioactive material to the environment and, as a result, the potential for exposure of individuals who lived in the vicinity of the site. The aircraft crash could result in mechanical damage to the storage casks and the fuel assemblies they contained, and a fire could result. The fire would provide an additional mechanism for dispersion of the radioactive material. The frequency and consequences of this event are described in detail in DIRS 103711-Davis, Strenge, and Mishima (1998, all).

The aircraft assumed for the analysis is a midsize twin-engine commercial jet (DIRS 103711-Davis, Strenge, and Mishima 1998, p. 2). The area affected by a crash was computed using the DOE standard formula (DIRS 101810-DOE 1996, Chapter 6) in which the aircraft could crash directly into the side or top of the concrete storage modules, or could strike the ground in the immediate vicinity of the facility and skid into the concrete storage modules. Using this formula, the dimensions of a typical storage facility as shown in Chapter 2, Figure 2-33, and the aircraft configuration would result in an estimated aircraft crash frequency of 0.0000032 (3 in 1 million) crashes per year (DIRS 103711-Davis, Strenge, and Mishima 1998, p. 5). This frequency is within the range that DOE typically considers the design basis, which is defined by DOE as 0.000001 or greater per year (DIRS 104601-DOE 1993, p. 28).

The analysis estimated the consequences of the aircraft crash on degraded concrete storage modules. The twin-engine jet was assumed to crash into an independent spent fuel storage installation that contained 100 concrete storage modules, each containing 24 pressurized-water reactor fuel assemblies. Using the penetration methodology from DIRS 101810-DOE (1996, Chapter 6), an aircraft crash onto these concrete storage modules could penetrate 0.8 meter (2.6 feet). Because the concrete storage modules have thicker walls, the crash projectiles would not penetrate the reinforced concrete in the as-constructed form. Thus, DOE determined that the aircraft crash would not cause meaningful consequences until the concrete storage modules were considerably degraded, when an aircraft projectile could penetrate a concrete storage module and damage a storage cask (DIRS 103711-Davis, Strenge, and Mishima 1998, p. 7). The degradation process is highly location-dependent, as noted in Section K.2.1.1. For sites in northern climates, the degradation would be relatively rapid due to the freeze/thaw cycling that would expedite concrete breakup; considerable degradation could occur in 200 to 300 years. For southern climates, the degradation would be much slower. Thus, an aircraft crash probably would not result in meaningful consequences for a few hundred to a few thousand years, depending on location. The timing is of some importance because the radioactive materials in the fuel would decay over time, and the potential for radiation exposure would decline with the decay.

The analysis assumed that the aircraft crash occurred 1,000 years after the termination of institutional control at a facility where the concrete had degraded sufficiently to allow breach of the dry storage canister. Computing public impacts from the air crash event requires estimating the population to a distance of 80 kilometers (50 miles) from a hypothetical site (the distance beyond which impacts from an airborne release would be very small). This analysis considered two such sites, one in an area of a high population site and one in an area of low population. The average population around all of the sites in each of the five regions defined in Figure K-2 was computed based on 1990 census data. The average ranged from a high of 330 persons per square mile in region 1 (high population) to a low of 77 persons per square mile in region 4 (low population). Both of these population densities (assumed to be uniform around the hypothetical sites) were used in the consequence calculation.

Estimating the amount of airborne respirable particles that would result from a crash requires assumptions about the impact and resulting fire. The impact of the jet engines probably would cause extensive damage to the fuel assemblies in the degraded concrete storage module. The fuel tanks in the aircraft would rupture, and fuel would disperse around the site, collect in pools, and ignite into a fire. The estimated fraction of the fuel converted to respirable airborne dust would be 0.12 percent (DIRS 103711-Davis, Strenge, and Mishima 1998, p. 9). The fire would cause a thermal updraft that could loft the fuel pellet dust into the atmosphere.

The consequences from the event were computed with the MACCS2 program (DIRS 101897-Jow et al. 1990, all). This model has been used extensively by the Nuclear Regulatory Commission and DOE to estimate impacts from accident scenarios involving releases of radioactive materials. The model computes dose to the public from the direct radiation by the cloud of radioactive particles released during the accident, from inhaling particles, and from consuming food produced from crops and grazing land that could be contaminated as the particles are deposited on the ground from the passing cloud. The food production and consumption rates are based on generic U.S. values (DIRS 103776-Kennedy and Strenge 1992, pp 6.19 to 6.28; DIRS 103168-Chanin and Young 1998, all). The program computes the dispersion of the particles as the cloud moves downwind. The dispersion would depend on the weather conditions (primarily wind speed, stability, and direction) that existed at the time of the accident. This calculation assumed median weather conditions and used annual weather data from airports near the centers of the regions.

K.2.5.2 Criticality

DOE evaluated the potential for nuclear criticality accidents involving stored spent nuclear fuel. A criticality accident is not possible in high-level radioactive waste because most of the fissionable atoms were removed or the density of fissionable atoms was reduced by the addition of glass matrix. Nuclear criticality is the generation of energy by the fissioning (splitting) of atoms as a result of collisions with neutrons. The energy release rate from the criticality event can be very low or very high, depending on several factors, including the concentration of fissionable atoms, the availability of moderating materials to slow the neutrons to a speed that enables them to collide with the fissionable atoms, and the presence of materials that can absorb neutrons, thus reducing the number of fission events.

Criticality events are of concern because under some conditions they could result in an abrupt release of radioactive material to the environment. If the event were energetic enough, the dry storage canister

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could split open, fuel cladding failure could occur, and fragmentation of the uranium dioxide fuel pellets could occur.

The designs of existing dry storage systems for spent nuclear fuel, in accordance with Nuclear Regulatory Commission regulations (10 CFR Part 72) preclude criticality events by various measures, including primarily the prevention of water entering the dry storage canister. If water is excluded, a criticality cannot occur.

If institutional control was maintained at the dry storage facilities (Scenario 1), a criticality is not plausible because the casks would be monitored and maintained such that introduction of water into the canister would not be possible. However, under Scenario 2, eventual degradation (corrosion) of the dry storage canisters could lead to the entry of water from precipitation, at which point criticality could be possible if other conditions were met simultaneously.

The analysis considered three separate criticality events:

- A low-energy event that involved a criticality lasting over an intermediate period (minutes or more). This event would not produce high temperatures or generate large additional quantities of radionuclides. Thus, no fuel cladding failures and no meaningful increase in consequences would be likely.

- An event in which a system went critical but at a slow enough rate so the energy release would not be large enough to produce steam, which would terminate the event. This event could continue over a relatively long period (minutes to hours), and would differ from the low-energy event in that the total number of fissions could be very large, and a large increase in radionuclide inventory could result. This increase could double the fission product content of the spent nuclear fuel. No fuel cladding failures would be likely in this event, so no abrupt release of radionuclides would occur.

- An energetic event in which a system went critical and produced considerable fission energy. This event could occur if seriously degraded fuel elements collapsed abruptly to the bottom of the canister in the presence of water that had penetrated the canister. This event would produce high fuel temperatures that could lead to cladding rupture and fuel pellet oxidation. The radiotoxicity of the radionuclide inventory produced by the fission process would be comparable to the inventory in the fuel before the event.

The probability of a criticality occurring as described in these scenarios is highly uncertain. However, DOE expects the probability would be higher for the first two events, and much lower for the third (energetic energy release). Several conditions would have to be met for any of the three events to occur. The concrete storage module and dry storage canister must have degraded such that water could enter but not drain out. The fuel would have to contain sufficient fissionable atoms (uranium-235, plutonium 239) to allow criticality. This would depend on initial enrichment (initial concentration of uranium-235) and burnup of the fuel in the reactor before storage (which would reduce the uranium-235 concentration). Because a small amount of spent nuclear fuel would be likely to have appropriate enrichment burnup combinations that could enable criticality to occur, none of the criticality events can be completely ruled out. The energetic criticality event is the only one with the potential to produce large impacts. Such an event would be possible, but would be highly unlikely; its consequences would be uncertain. The event could cause a prompt release of radionuclides. However, the amount released would not be likely to exceed that released by the aircraft crash event evaluated above. Thus, this analysis did not evaluate specific consequences of a criticality event.

K.3 Results

K.3.1 RADIOLOGICAL IMPACTS

Impacts to human health from long-term environmental releases and human intrusion were estimated using the methods described in Section K.2 and in supporting technical documents (DIRS 101925-Sinkowski 1998, all; DIRS 101852-Jenkins 1998, all; DIRS 104597-Battelle 1998, all; DIRS 101910, 101911-Poe 1998, all; DIRS 101912-Poe and Wise 1998, all; DIRS 101935-Toblin 1999, all; DIRS 101936-Toblin 1999, all; DIRS 101937-Toblin 1998, all). The radiological impacts on human health would include internal exposures due to the intake of radioactive materials released to surface water and groundwater.

Six of the seven radionuclides listed in Table K-4 would contribute more than 99 percent of the total dose. Table K-11 lists the estimated radiological impacts by region during the last 9,900 years under Scenario 2 for the Proposed Action and Module 1 inventories of spent nuclear fuel and high-level radioactive waste. As noted above, these impacts would be to the public from drinking water from the major waterways contaminated by surface-water runoff of radioactive materials from degraded spent nuclear fuel and high-level radioactive waste storage facilities (DIRS 101935-Toblin 1999, all; DIRS 101936-Toblin 1999, all). Figure K-7 shows the locations of all commercial nuclear and DOE waste storage sites in the United States and more than 20 potentially affected major waterways. At present, 30.5 million people are served by municipal water systems with intakes along the potentially affected portions of these waterways. Over the 9,900-year analysis period, about 140 generations would be potentially affected. However, because releases are not estimated to occur during about the first 1,000 years for most regions, the potential affected population could be as high as 3.9 billion.

SCENARIO 2 IMPACTS

The principal long-term human health consequences from the storage of spent nuclear fuel and high-level radioactive waste would result from rainwater flowing through degraded storage facilities where it would dissolve the material. The dissolved material would travel through groundwater and surface-water runoff to rivers and streams where people could use it for domestic purposes such as drinking water and crop irrigation. The Scenario 2 analysis estimated population impacts resulting only from the consumption of contaminated drinking water and exposures resulting from land contamination due to periodic flooding, although other pathways, such as eating contaminated fish, could contribute additional impacts larger than those from drinking water for selected individuals in the exposed population.

Table K-11 indicates the variability of collective doses and potential impacts in the five regions analyzed (see Section K.2.1.6). The variability among regions is due to differences in types and quantities of spent nuclear fuel and high-level radioactive waste, annual precipitation, size of affected populations, and surface-water bodies available to transport the radioactive material.

Table K-11 also indicates that the Proposed Action inventory would produce a collective drinking water dose of 6.6 million person-rem over 9,900 years, which could result in an additional 3,300 latent cancer fatalities in the total potentially exposed population of 3.9 billion, in which about 900 million fatal cancers [using the lifetime fatal cancer risk of 24 percent (DIRS 101849-NCHS 1993, p. 5)] would be likely to occur from all other causes. Figures K-8 and K-9 show the Proposed Action inventory regional collective doses and potential latent cancer fatalities, respectively, for approximately 140 consecutive 70-year lifetimes that would occur during the 9,900-year analysis period. The peaks shown in Figures K-8 and K-9 would result from the combination of the sites that drain to the Mississippi River and the relatively large populations potentially affected along these waterways. These values include

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Table K-11. Estimated collective radiological impacts to the public from continued storage of Proposed Action and Module 1 inventories of spent nuclear fuel and high-level radioactive waste at commercial and DOE storage facilities – Scenario 2.[a]

	9,900-year population dose[b] (person-rem)		9,900-year LCFs		Years until peak impact[c]	
Region	Proposed Action	Module 1	Proposed Action	Module 1	Proposed Action	Module 1
1	1,800,000	1,820,000	900	900	1,400	1,400
2	760,000	1,260,000	380	630	5,100	8,300
3	3,500,000	3,650,000	1,800	1,830	3,400[d]	3,400[d]
4	70,000	138,000	30	69	3,900	3,900
5	460,000	461,000	230	230	7,100	7,000
Totals	***6,590,000***	***7,330,000***	***3,340***	***3,700***		

a. Total population (collective) dose from drinking water pathway over 9,900 years.
b. LCF = latent cancer fatality; additional number of latent cancer fatalities for the exposed population group based on an assumed risk of 0.0005 latent cancer fatality per person-rem of collective dose (DIRS 101857-NCRP 1993, p. 112).
c. Years after 2116 when the maximum doses would occur.
d. Year of combined U.S. peak impact would be the same as for Region 3 peak impact, because the predominant impact would be in Region 3.

impacts for the Proposed Action inventory only. Similar curves for the Module 1 inventory are not shown because of their similarity to those for the Proposed Action inventory. As listed in Table K-11, the impacts from the Module 1 inventory would be approximately 20 percent greater than for the Proposed Action inventory.

The additional 3,300 Proposed Action latent cancer fatalities (or 3,700 Module 1 latent cancer fatalities) over the 10,000-year analysis period would not be the only negative impact. Under Scenario 2, more than 20 major waterways of the United States (for example, the Great Lakes, the Mississippi, Ohio, and Columbia rivers, and many smaller rivers along the Eastern Seaboard) that currently supply domestic water to 30.5 million people would be contaminated with radioactive material. The shorelines of these waterways would be contaminated with long-lived radioactive materials (plutonium, uranium, americium, etc.) that would result in exposures to individuals who came into contact with the sediments, potentially increasing the number of latent cancer fatalities. Each of the 72 commercial and 5 DOE sites throughout the United States would have potentially hundreds of acres of land and underlying groundwater systems contaminated with radioactive materials at concentrations that would be potentially lethal to anyone who settled near the degraded storage facilities. The radioactive materials at the degraded facilities and in the floodplains and sediments would persist for hundreds of thousands of years.

As mentioned above, DOE only estimated potential collective impacts resulting from the consumption of contaminated surface water. However, other pathways (food consumption, contaminated floodplains, etc.) that could contribute to collective dose were evaluated (DIRS 101936-Toblin 1999, all; DIRS 150990-Rollins 1998, all) to determine their relative importance to the drinking water pathway. These pathways included the following:

- Consumption of vegetables irrigated with contaminated water
- Consumption of meat and milk from animals that drank contaminated water or were fed with contaminated feed
- Consumption of contaminated finfish and shellfish
- Direct exposure to contaminated shoreline sediments
- Exposures resulting from contamination of floodplains during periods of high stream (river) flow

These analyses determined that an individual living in a contaminated floodplain and consuming vegetables irrigated with contaminated surface water could receive a radiation exposure dose three times

Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Note: The Great Lakes and the St. Lawrence Seaway are considered major waterways.

Source: Modified from DIRS 101911-Poe (1998, p. 13).

Figure K-7. Major waterways near commercial and DOE sites.

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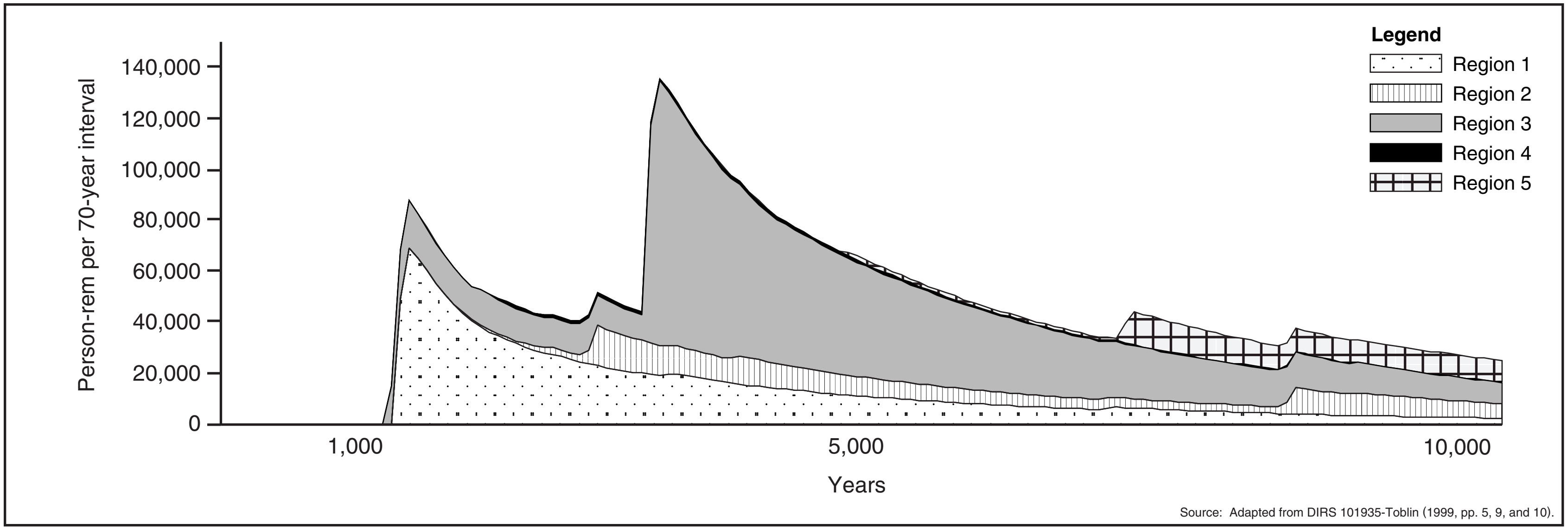

Figure K-8. Regional collective dose from the Proposed Action inventory under No-Action Scenario 2.

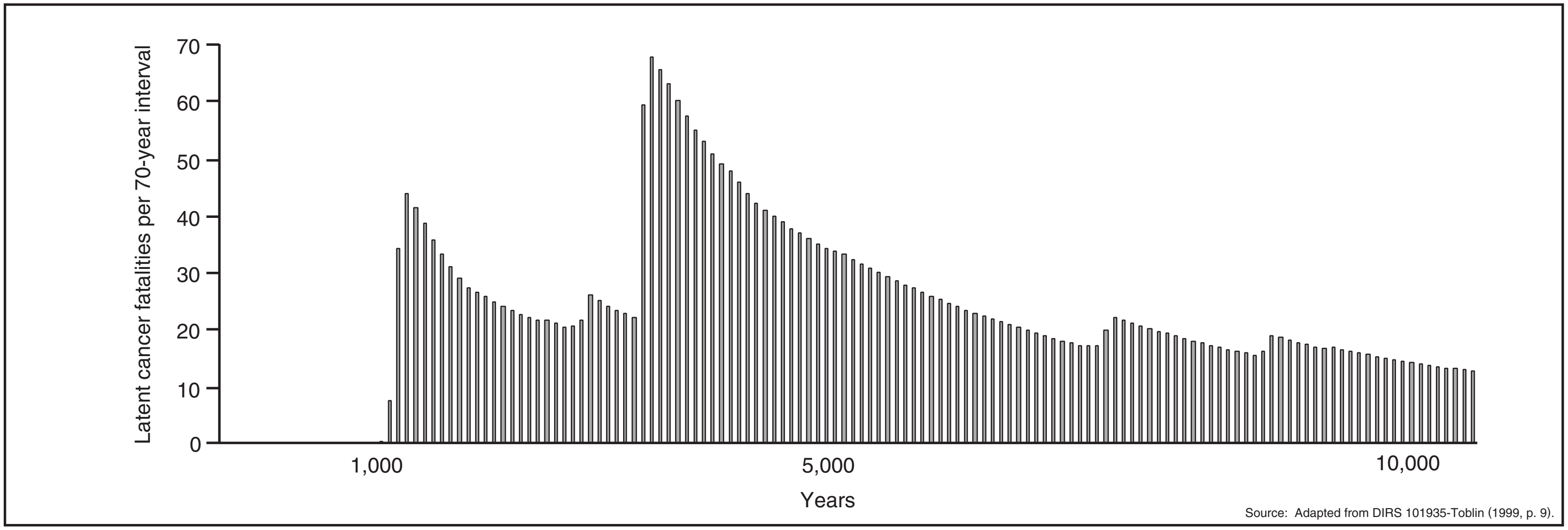

Figure K-9. Total potential latent cancer fatalities throughout the United States from the Proposed Action inventory under No-Action Scenario 2.

higher than that from the consumption of contaminated surface water only (DIRS 101936-Toblin 1999, p. 3). In addition, the analysis determined that impacts to 30 million individuals potentially living in contaminated floodplains would be less than 10 percent of the collective impacts shown in Figure K-9 and, therefore, did not include them in the estimates because DOE did not want to overestimate the impacts from Scenario 2.

DOE evaluated airborne pathways (DIRS 147905-Mishima 1998, all) and judged that potential impacts from those pathways would be very small in comparison to impacts from liquid pathways because the degraded facility structures would protect the radioactive material from winds. To simplify the analysis, impacts to the public from radiation emanating from the degraded storage facilities were not included. Those impacts were judged to represent a small fraction of the impacts calculated for the liquid pathways (Table K-11).

Estimates of localized impacts (DIRS 101937-Toblin 1998, p. 1) assumed that individuals (onsite and near-site gardeners) would take up residence near the degraded storage facilities and would consume vegetables from their gardens irrigated with groundwater withdrawn from the contaminated aquifer directly below their locations. In addition, the onsite gardener would be exposed to external radiation emanating from the exposed dry storage canisters; therefore, the onsite gardener would be the maximally exposed individual.

Table K-12 lists the internal estimated dose rates (see Section K.2.4.1 for details) and the times for peak exposure for each of the five regions.

Table K-12. Estimated internal dose rates (rem per year) and year of peak exposure[a] (in parentheses) for the onsite and near-site gardeners – Scenario 2.[b]

	Maximally exposed individual distances (meters)[c] from storage facilities			
Region	10[d]	150	1,000	5,000
1	3,100 (1,800)	670 (2,200)	51 (2,000)	12 (2,600)
2	100 (2,700)	96 (2,000)	12 (2,900)	2 (7,100)
3	3,100 (1,800)	1,800 (2,000)	150 (2,600)	31 (6,000)
4	140 (3,200)	130 (3,900)	14 (4,800)	2 (9,300)
5	3,300 (4,600)	180 (5,300)	59 (5,300)	2 (6,100)

a. Years after facility maintenance ended.
b. Source: Adapted from DIRS 101937-Toblin (1998, Table 4, p. 5).
c. To convert meters to feet, multiply by 3.2808.
d. The maximally exposed individual would be the onsite gardener.

The regional dose rates listed in Table K-12 would depend on the concentration of contaminants (primarily plutonium) in the underlying aquifer from which water was extracted and used by the gardener for consumption and crop irrigation. These aquifer concentrations, in turn, would be affected by the type and location of stored materials (spent nuclear fuel and high-level radioactive waste) in each region, the rate at which the contaminants were leached from the stored material, the amount of water (precipitation) available for dilution, and the thickness of the aquifer. For example, releases in Region 5 would probably be smaller and would occur later than those in other regions because of the region's lack of precipitation. This is indeed the case for commercial fuel, which is stored in above-grade concrete storage modules, stainless-steel dry storage canisters, and mostly intact corrosion-resistant zirconium alloy cladding.

However, early releases would occur in Region 5 because most DOE spent nuclear fuel is stored in below-grade vaults (see Appendix A, p. A-25) that would stop providing rain protection after 50 years (see Section K.2.1.1 for details). In addition, the analysis assumed no credit for the protectiveness of the DOE spent nuclear fuel cladding (see Section K.2.1.4.2 for details), which would result in releases that began early (about 800 years after weather protection was lost) and persist at a nearly constant rate for more that 6,000 years (DIRS 101937-Toblin 1998, p. 3).

The 10-meter (33-foot) doses listed in Table K-12 would be due to leachate concentrations from the storage area with no groundwater dilution. Downgradient doses decrease more rapidly in Regions 1 and 5 than in other regions because of greater groundwater dilution. The downgradient decrease in Region 5 would also be due to the relatively thick aquifer, which results in greater vertical plume spread and increases plume attenuation (DIRS 101937-Toblin 1998, pp. 4 to 6).

As shown in Table K-12, an onsite gardener in Region 5 could receive an internal committed dose as high as 3,300 rem for each year of ingestion of plutonium-239 and -240. However, the individual actually would receive only about 70 rem the first year, 140 rem the second year, 210 rem the third year, and so on until reaching an equilibrium annual dose (in approximately 50 years) of 3,300 rem per year. The individual would continue to receive this equilibrium dose as long as the radioactive material uptake remained constant.

If the annual doses are added, in less than 10 years the individual would have received more than 2,000 rem. If the International Commission on Radiological Protection risk conversion factor were applied to this dose, a probability of fatal cancer induction of 1 could be calculated. In other words, the use of this risk conversion would predict that 10 years of exposure would be virtually certain to produce a fatal cancer. This calculated risk is approximately 4 times greater than the lifetime risk of contracting a fatal cancer from all other causes (24 percent).

Table K-13 shows that the direct radiation dose rate to the onsite gardener could be as high as 7,300 rem per year. Unlike internal dose, this dose would actually be delivered during the year of exposure. This maximum value assumes a complete loss of shielding normally provided by the concrete storage module at the same time as the loss of weather protection (see Table K-1). Assuming a dose of 7,300 rem per year, the individual probably would die from acute radiation exposure. This dose would probably cause extensive cell damage in the individual that would result in severe acute adverse health conditions and death within weeks or months (DIRS 106184-NRC 1996, p. 8.29-5). However, these higher radiation dose rates are based on an early estimated time to structural failure of the concrete storage module. If these failure times were extended by as little as 100 years, the associated dose rates would decrease by a factor of 10 because the levels of radiation emanating from the degraded facilities would have decreased by about a factor of 10 due to radioactive decay (DIRS 150990-Rollins 1998, p. 12).

Table K-13. Estimated external peak dose rates (rem per year) for the onsite and near-site gardeners – Scenario 2.

		Maximally exposed individual distances (meters)[a] from storage facilities			
Region	Year of peak exposure[b]	10[c]	150	1,000	5,000
1	190	7,200	4	0.001	0.0
2	800	28	0.04	0.0	0.0
3	170	7,300	4	0.001	0.0
4	850	31	0.04	0.0	0.0
5	3,600	32	0.05	0.0	0.0

a. To convert meters to feet, multiply by 3.2808.
b. Years after 2116; Source: Adapted from DIRS 101910-Poe (1998, all).
c. Source: Adapted from (DIRS 101556-Davis 1998, all); the maximally exposed individual would be the onsite gardener.

The internal and external dose rates are presented separately because they would occur at different times and are therefore not additive.

K.3.2 UNUSUAL EVENTS

This section includes a quantitative assessment of potential accident impacts and a qualitative discussion of the impacts of sabotage.

K.3.2.1 Accident Scenarios

The analysis examined the impacts of accident scenarios that could occur during the above-ground storage of spent nuclear fuel and high-level radioactive waste and concluded that the most severe accident scenarios would be an aircraft crash into concrete storage modules or a severe seismic event. In Scenario 1, where storage would be in strong rigid concrete storage modules that had not degraded, the accident would not be expected to release radioactive material.

In Scenario 2, the concrete storage modules would deteriorate with time. If a severe natural event (for example, a hurricane) were to strike a degraded facility, a release of radioactive materials could occur earlier than predicted (see Section K.2) because of damage to the engineered barriers (concrete storage modules, dry storage canisters, material cladding, etc.). Section K.4 describes the potential effect of early loss of these barriers (see Table K-15 in Section K.4.3.1). However, DOE concluded that an aircraft crash into degraded concrete storage modules would dominate the consequences. The analysis evaluated the potential for criticality accidents and concluded that an event severe enough to produce meaningful consequences would be extremely unlikely, and that the consequences would be bounded by the aircraft crash consequences. Table K-14 lists the consequences of an aircraft crash on a degraded spent fuel concrete storage module.

Table K-14. Consequences of aircraft crash onto degraded spent nuclear fuel concrete storage module.[a]

Factor	High-population site[b]	Low-population site[c]
Frequency (per year)	3.2×10^{-6}	3.2×10^{-6}
Collective population dose (person-rem)	26,000	6,000
Latent cancer fatalities	13	3

a. Source: DIRS 103711-Davis, Strenge, and Mishima (1998, p. 11).
b. 330 persons per square mile.
c. 77 persons per square mile.

K.3.2.2 Sabotage

Storage of spent nuclear fuel and high-level radioactive waste over 10,000 years would entail a continued risk of intruder access at each of the 77 sites. Sabotage could result in a release of radionuclides to the environment around the facility. In addition, intruders could attempt to remove fissile material, which could result in releases of radioactive material to the environment. For Scenario 1, the analysis assumed that safeguards and security measures currently in place would remain in effect during the 10,000-year analysis period at the 77 sites. Therefore, the risk of sabotage would continue to be low. However, the difficulty of maintaining absolute control over 77 sites for 10,000 years would suggest that the cumulative risk of intruder attempts would increase.

For Scenario 2, the analysis assumed that safeguards and security measures would not be maintained at the 77 sites after approximately the first 100 years. For the remaining 9,900 years of the analysis period, the cumulative risk of intruder attempts would increase. Therefore, the risk of sabotage would increase substantially under this scenario.

K.4 Uncertainties

Section K.3 contains estimates of the radiological impacts of the No-Action Alternative, which assumes continued above-ground storage of spent nuclear fuel and high-level radioactive waste at sites across the United States. Associated with the impact estimates are uncertainties typical of predictions of the outcome of complex physical and biological phenomena and of the future state of society and societal institutions over long periods. DOE recognized this fact from the onset of the analysis; however, the predictions will be valuable in the decisionmaking process because they provide insight based on the best information and scientific judgments available.

This analysis considered five aspects of uncertainty:

- Uncertainties about the nature of changes in society and its institutions and values, in the physical environment, and of technology as technology progresses
- Uncertainties associated with future human activities and lifestyles
- Uncertainties associated with the mathematical representation of the physical processes and with the data in the computer models
- Uncertainties associated with the mathematical representation of the biological processes involving the uptake and metabolism of radionuclides and the data in the computer models
- Uncertainties associated with accident scenario analysis

The following sections discuss these uncertainties in the context of possible effects on the impact estimates reported in Chapter 7 and Section K.3.

K.4.1 SOCIETAL VALUES, NATURAL EVENTS, AND IMPROVEMENTS IN TECHNOLOGY

K.4.1.1 Societal Values

History is marked by periods of great social upheaval and anarchy followed by periods of relative political stability and peace. Throughout history, governments have ended abruptly, resulting in social instability, including some level of lawlessness and anarchy. The Scenario 1 assumption is that political stability would exist to the extent necessary to ensure adequate institutional control to monitor and maintain the spent nuclear fuel and high-level radioactive waste to protect the workers and the public for 10,000 years. The Scenario 2 assumption is that in the United States political stability would exist for 100 years into the future and that the spent nuclear fuel and high-level radioactive waste would be properly monitored and maintained and the public would be protected for this length of time. If a political upheaval were to occur in the United States, the government could have difficulty protecting and maintaining the storage facilities, and the degradation processes could begin earlier than postulated in Scenario 2. If institutional control were not maintained for at least 100 years, radioactive materials from the spent nuclear fuel and high-level radioactive waste could enter the environment earlier, which would result in higher estimated impacts due to the higher radiotoxicity of the materials. However, this scenario would probably increase overall impacts by no more than a factor of 2.

K.4.1.2 Changes in Natural Events

Because of the difficulty of predicting impacts of climate change (glaciation, precipitation, global warming), DOE decided to evaluate facility degradation and environmental transport mechanisms based on current climate conditions. For example, glaciation, which many scientists agree will occur again within 100,000 years, probably would cover the northeastern United States with a sheet of ice. The ice would crush all structures, including spent nuclear fuel and high-level radioactive waste storage facilities, and could either disperse the radioactive materials in the accessible environment or trap the materials in the ice sheet. In addition, large populations would migrate from the northeastern United States to warmer climates, thus changing the population distribution and densities throughout the United States (the coastline could move 100 miles out from its current position due to the reduced water in the oceans). Other scientists predict that global warming could lead to extensive flooding of low-lying coastal areas throughout the world. Such changes would have to be known with some degree of certainty to make accurate estimates of potential impacts associated with the release of spent nuclear fuel and high-level radioactive waste materials to the environment. To simplify the analysis, DOE has chosen not to attempt to quantify the impacts resulting from the almost certain climate changes that will occur during the analysis period.

K.4.1.3 Improvements in Technology

We are living in a time of unparalleled technical advancement. It is possible that cures for many common cancers will be found in the coming decades. In this regard, the National Council on Radiation Protection and Measurements (DIRS 101858-NCRP 1995, p. 51) states that:

> *One of the most important factors likely to affect the significance of radiation dose in the centuries and millennia to come is the effect of progress in medical technology. At some future time, it is possible that a greater proportion of somatic [cancer] diseases caused by radiation will be treated successfully. If, in fact, an increased proportion of the adverse health effects of radiation prove to be either preventable or curable by advances in medical science, the estimates of long-term detriments may need to be revised as the consequences (risks) of doses to future populations could be very different.*

Effective cures for cancer would affect the fundamental premise on which the No-Action Alternative impact analysis is based. However, this technology change was not included in the impact analyses.

Other advancements in technology could include advancements in water purification that could reduce the concentration of contaminants in drinking water supplies. Improved corrosion-resistant materials could reduce package degradation rates, which could reduce the release of contaminants and the resultant impacts. In addition, future technology could enable the detoxification of the spent nuclear fuel and high-level radioactive waste materials, thereby removing the risks associated with human exposure.

K.4.2 CHANGES IN HUMAN BEHAVIOR

General guidance for the prediction of the evolution of society has been provided by the National Research Council in *Technical Bases for Yucca Mountain Standards* (DIRS 100018-National Research Council 1995, pp. 28 and 70), in which the Committee on Technical Bases for Yucca Mountain Standards concluded that there is no scientific basis for predicting future human behavior. The study recommends policy decisions that specify the use of default (or reference) scenarios to incorporate future human behaviors into compliance assessment calculations. This No-Action Alternative analysis followed this approach, based on societal conditions as they exist today. In doing so, the analysis assumed that populations would remain at their present locations and that population densities would remain at the current levels. This assumption is appropriate when estimating impacts for comparison with other proposed actions; however, it does not reflect reality.

Although this analysis did not project the affected populations used in the No-Action Alternative to 2035, as DOE has done in other parts of the EIS, the potential effect on the outcome would be an increase in collective impacts of less than a factor of 1.5, which is the average expected increase in national population from 1990 to 2035 (DIRS 152471-Bureau of the Census 2000, all). In addition to changing in size, populations are constantly moving. If, for example, populations were to move closer to and increase in size in areas near the storage facilities, the radiation dose and resultant adverse impacts could increase substantially. However, DOE has no way to predict such changes accurately and, therefore, did not attempt to quantify the resultant effects on overall impacts.

Another lifestyle change that could affect the overall impacts would involve food consumption patterns. For example, people might curtail their use of public water supplies derived from rivers if they learned that the river water carried carcinogens. Widespread adoption of such practices could reduce the impacts associated with the drinking water pathway.

K.4.3 MATHEMATICAL REPRESENTATIONS OF PHYSICAL PROCESSES AND OF THE DATA INPUT

The DOE approach for the No-Action Alternative was to be as comparable as possible to the approach used for the predictions of impacts from the proposed Yucca Mountain Repository to enable direct comparisons of the impact estimates for the two cases. Therefore, the analysis either used the process models developed for the TSPA-VA directly or adapted them for the No-Action Alternative impact calculations. For processes that were different from those treated in the TSPA-VA, DOE developed analytical approaches.

In a general sense, the TSPA-VA calculations used a stochastic (random) approach to develop radiological impact estimates. Existing process models were used to generate a set of responses for a particular process. In the TSPA-VA process, the impact calculations sample each set of process responses and calculate a particular impact result. A large number of calculations were performed. From the set of variable results, an expected value can be identified, as can a distribution of results that is an indication of the uncertainties in the calculated expected values.

For the No-Action Alternative analysis, the calculations were based on only a single set of best estimate parameters. No statistical distribution of results was generated as a basis for the quantification of uncertainties. This section describes the uncertainties associated with the input data and modeling used to evaluate the rates of degradation of the materials considered in this document and to estimate the impacts of the resulting releases. It describes the key assumptions, shows where the assumptions are consistent with TSPA-VA assumptions, and qualitatively assesses the magnitude of the uncertainties caused by the assumptions.

Calculating the radiological impacts to human receptors required a mathematical representation of physical processes (for example, water movement) and data input (for example, material porosity). There are uncertainties in both the mathematical representations and in the values of data. The TSPA-VA accommodates these uncertainties by using a probabilistic approach to incorporate the uncertainties, whereas the No-Action analysis uses a deterministic approach in combination with an uncertainty analysis. When done correctly, both approaches yield the same information, although, as in the case of the TSPA-VA, the probabilistic approach provides quantitative information.

K.4.3.1 Waste Package and Material Degradation

The major approaches and assumptions used for the No-Action Scenario 2 analysis are listed in Table K-15. The table indicates where the continued storage calculations followed the basic methods developed for the TSPA-VA. It also indicates the processes for which models other than those used in the TSPA-VA were applied.

DOE analyzed surface storage of commercial spent nuclear fuel in horizontal stainless-steel canisters inside concrete storage modules. There are other probable forms of storage, including horizontal and

Table K-15. Review of approaches, assumptions, and related uncertainties[a] (page 1 of 2).

Approach or assumption	Consistent with repository analysis assumptions	Sensitivity of impacts to approach or assumption[b]
Period of analysis – 10,000 years	Yes	None
Commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste quantities equivalent to NWPA specified 70,000 MTHM and Module 1	Yes	None
No credit for stainless-steel cladding on commercial spent nuclear fuel	Yes	If credit were taken for stainless-steel cladding, LCFs[a] could decrease by as much as a factor of 10.
0.1 percent of zirconium alloy cladding is initially failed	Yes	If initial zirconium-alloy-clad fuel cladding failure had been assumed to be as low as zero or as high as 100 percent impacts could have been slightly smaller (additional protection from winds) to a factor of 20 higher, respectively.
Concrete storage module weather protection	This is a primary protective barrier for the No-Action analysis and is not applicable to TSPA	If weather protection from the concrete storage module had not been assumed in the No-Action analysis, LCFs could be higher by less than a factor of 10.
Concrete base pad degradation	Not applicable	Used NRC recommended values (probably overestimated degradation and reduced consequences in the No-Action analysis); increase in LCFs by probably more than a factor of 2 but less than a factor of 10
Credit for stainless-steel canister on high-level radioactive waste	No; TSPA does not take credit for stainless-steel container	If the No-Action analysis had not taken credit for the stainless-steel canister, LCFs would change very little (slight increase) because of the intrinsic stability of the borosilicate glass.
DOE spent nuclear fuel evaluated by a representative surrogate that is based mostly on DOE N-Reactor spent nuclear fuel (other spent nuclear fuel types not evaluated)	Yes	If actual fuel types were evaluated, LCFs could either increase or decrease by less than a factor of 2.
No credit given for zirconium alloy cladding on N-Reactor spent nuclear fuel	Yes	If credit was given for the N-Reactor zirconium alloy cladding, the LCFs would decrease by less than a factor of 2.
Stainless steel deterioration	Model paralleled TSPA approach for Alloy-22	Model based on best information; if incorrect and corrosion proceeds more rapidly and stainless steel offers no protection, LCFs would increase by less than 25 percent.
Zirconium alloy cladding deterioration	Yes, very slow corrosion rate.	If the No-Action analysis had assumed larger or smaller deterioration rates, LCFs could have increased by several orders of magnitude or decreased by less than a factor of 2.
Zirconium alloy cladding credit	Yes	If the No-Action analysis had not taken credit for zirconium alloy cladding, LCFs could have increased by as much as 2 orders of magnitude.
Deterioration of spent nuclear fuel and high-level radioactive waste core materials	Yes	None

Table K-15. Review of approaches, assumptions, and related uncertainties[a] (page 2 of 2).

Approach or assumption	Consistent with repository analysis assumptions	Sensitivity of impacts to approach or assumption[b]
Use of recent regional climate conditions to determine deterioration (temperature, precipitation, etc.)	No; No-Action analysis used constant "effective" regional weather parameters weighted for material inventories and potentially affected downstream populations; TSPA used actual weather patterns measured at Yucca Mountain. The TSPA also assumed long-term climate changes would occur in the form of increased precipitation.	If actual site climate data and projected future potential climate changes had been considered in the No-Action analysis, LCFs could have increased or decreased by as much as a factor of 10. Climate change assumptions such as a glacier covering most of the northeastern seaboard of the United States would have made estimating impacts from continued storage virtually impossible.
Surface transport by precipitation	Not applicable; TSPA only considered groundwater transport because there is no surface-water transport pathway possible for the repository.	If the No-Action analysis had not considered the groundwater transport pathway, LCFs could have been as much as a factor of 10 higher.
Regional binning of sites – not specific site parameters	Not applicable; TSPA considered only a single site; the No-Action analysis evaluated potential impacts from 77 sites on a regional basis.	The No-Action analysis binned sites into categories and developed "effective" regional climate conditions such that calculated impacts would be comparable to those which could be calculated by a site-specific analysis.
Atmospheric dose consequences judged to be small when compared to liquid pathways.	Yes	Small impact on LCFs.
Drinking water doses	Yes; primary pathway evaluated	Use of drinking-water-only pathway underestimates total collective LCFs by less than a factor of 3.
Used the Multimedia Environmental Pollutant Assessment System[c] modeling approach for calculating population uptake/ingestion	No; TSPA uses GENII-S.[d] GENII-S uses local survey data; the Multimedia Environmental Pollutant Assessment System uses EPA/NRC exposure/uptake default and actual population data	No impact. The two programs yield comparable results as used in these analyses.
ICRP[e] approach to calculate dose commitment from ingested radionuclides	Yes	No impact.
Human health impacts calculated as LCFs with NCRP[f] conversion factors	NA; TSPA does not estimate LCFs.	Use of other than the linear no-threshold model could result in a change in estimated LCFs from 0.25 to 2 times the nominal value.[g]

a. Abbreviations: NWPA = Nuclear Waste Policy Act; MTHM = metric tons of heavy metal; LCF = latent cancer fatality; TSPA = Total System Performance Assessment; NRC = Nuclear Regulatory Commission; ICRP = International Commission on Radiological Protection; EPA = Environmental Protection Agency.

b. Sensitivity of impacts to approach/assumption is based on professional judgement and, if applicable, the effects of the approaches/ assumptions on calculations.

c. DIRS 101533-Buck et al. (1995, all).

d. DIRS 100464-Leigh et al. (1993, all).

e. DIRS 110386-ICRP (1979, all).

f. DIRS 101857-NCRP (1993, p. 112).

g. DIRS 101884-NCRP (1997, p. 75).

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vertical casks made of materials ranging from stainless steel to carbon steel. Degradation and releases from vertical carbon-steel casks were evaluated qualitatively. Such storage units would be likely to fail from corrosion earlier than concrete and stainless steel. The concrete and stainless-steel units were calculated to fail and begin releasing their contents at about 1,000 years after the assumed loss of institutional control. The less-resistant carbon-steel units could begin releasing their contents earlier and their use would result in a longer period of release and increased impacts. This difference is likely to be an increase of 10 to 30 percent in population dose commitment and resultant latent cancer fatalities.

K.4.3.2 Human Health Effects

The dose-to-risk conversion factors typically used to estimate adverse human health impacts resulting from radiation exposures contain considerable uncertainty. The risk conversion factor of 0.0005 latent cancer fatality per person-rem of collective dose for the general public typically used in DOE National Environmental Policy Act documents is based on recommendations of the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, p. 22) and the National Council on Radiation Protection and Measurements (DIRS 101857-NCRP 1993, p. 112). The factor is based on health effects observed in the high dose and high dose rate region (20 to 50 rem per year). Health effects were extrapolated to the low-dose region (less than 10 rem per year) using the linear no-threshold model. This model is generally recommended by the International Commission on Radiological Protection and the National Council of Radiation Protection and Measurements, and most radiation protection professionals believe this model produces a conservative estimate (that is, an overestimate) of health effects in the low-dose region, which is the exposure region associated with continued storage of spent nuclear fuel and high-level radioactive waste. This report summarizes estimates of the impacts associated with very small chronic population doses to enable comparison of alternatives in this EIS.

According to the National Council on Radiation Protection and Measurements, the results of an analysis of the uncertainties in the risk coefficients "show a range (90 percent confidence intervals) of uncertainty values for the lifetime risk for both a population of all ages and an adult worker population from about a factor of 2.5 to 3 below and above the 50th percentile value" (DIRS 101884-NCRP 1997, p. 74).

The National Council on Radiation Protection and Measurements states, "This work indicates that given the sources of uncertainties considered here, together with an allowance for unspecified uncertainties, the values of the lifetime risk can range from about one-fourth or so to about twice the nominal values" (DIRS 101884-NCRP 1997, p. 75).

Because of the large uncertainties that exist in the dose/effect relationship, the Health Physics Society has recommended "…against quantitative estimation of health risks due to radiation exposure below a lifetime dose of 10 rem …" (DIRS 101835-Mossman et al. 1996, p. 1). In essence, the Society has recommended against the quantification of risks due to individual radiation exposures comparable to those estimated in the No-Action analysis. These uncertainties are due, in part, to the fact that epidemiological studies have been unable to demonstrate that adverse health effects have occurred in individuals exposed to small doses (less than 10 rem per year) over a period of many years (chronic exposures) and to the fact that the extent to which cellular repair mechanisms reduce the likelihood of cancers is unknown.

Other areas of uncertainty in estimation of dose and risk include the following:

- *Uncertainties Related to Plant and Human Uptake of Radionuclides.* There are large uncertainties related to the uptake (absorption) of radionuclides by agricultural plants, particularly in the case where "regionalized," versus "site-specific" data are used. Also of importance are variations in the absorption of specific radionuclides through the human gastrointestinal tract. Factors that influence the absorption of radionuclides include their chemical or physical form, their concentrations, and the presence of stable elements having similar chemical properties. In the case of agricultural crops, many of these factors are site-specific.

- *Uncertainties in Dose and Risk Conversion Factors.* The magnitudes and sources of the uncertainties in the various input parameters for the analytical models need to be recognized. In addition to the factors cited above, these include those required for converting absorbed doses into equivalent doses, for calculating committed doses, and for converting organ doses into effective (whole body) doses. Although these various factors are commonly assigned point values for purposes of dose and risk estimates, each of these factors has associated uncertainties.

- *Conservatisms in Various Models and Parameters.* In addition to recognizing uncertainties, one must take into account the magnitudes and sources of the conservatisms in the parameters and models being used. These include the fact that the values of the tissue weighting factors and the methods for calculating committed and collective doses are based on the assumption of a linear no-threshold relationship between dose and effect. As the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements have stated, the use of the linear no-threshold hypothesis provides an upper bound on the associated risk (DIRS 147927-ICRP 1966, p. 56). Also to be considered is that the concept of committed dose could overestimate the actual dose by a factor of 2 or more (DIRS 101856-NCRP 1993, p. 25).

K.4.3.3 Accidents and Their Uncertainty

The accident methodology used in this analysis is described in Section K.2.5 for Scenarios 1 and 2. It states that for Scenario 1 an aircraft crash into the storage array would provide the most severe accident scenario and its consequences would not cause a release from the rugged concrete storage module. The analysis placed considerable weight on the quality and strength of the concrete storage module and dry storage canister. For an analysis extending 10,000 years, more severe natural events can be postulated than those used as the design basis for the dry storage canister, and they could cause failure of the canister. This could exceed the consequences estimated for Scenario 1, but it would be unlikely to exceed the consequences for the aircraft accident scenario evaluated for Scenario 2.

Section K.2.5.1 concludes that the aircraft crash on the degraded concrete storage modules would be the largest credible event that could occur. The best estimate impacts from this event ranged from 3 latent cancer fatalities for a low-population site to 13 for a high-population site. The uncertainties in these estimates are very large. As discussed above, the aircraft crash could cause a minimum of no latent cancer fatalities given the uncertainty in the model that converts doses to cancers. The maximum impact could be substantially greater than the estimated values if an aircraft crash involving the largest commercial jet occurred at the time of initial concrete storage module degradation at a specific site under adverse weather conditions (conditions that would maximize the offsite doses) involving spent fuel with the maximum expected inventory of radionuclides.

K.4.4 UNCERTAINTY SUMMARY

The sections above discuss qualitatively and semiquantitatively the uncertainties associated with impact estimates resulting from the long-term storage of spent nuclear fuel and high-level radioactive waste at multiple sites across the United States. As stated above, DOE has not attempted to quantify the variability of estimated impacts related to possible changes in climate, societal values, technology, or future lifestyles. Although uncertainties with these changes could undoubtedly affect the total consequences reported in Section K.3 by several orders of magnitude, DOE did not attempt to quantify these uncertainties to simplify the analysis.

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DOE attempted to quantify a range of uncertainties associated with mathematical models and input data, and estimated the potential effect these uncertainties could have on collective human health impacts. By summing the uncertainties discussed in Sections K.4.1, K.4.2, and K.4.3 where appropriate, DOE estimates that total collective impacts over 10,000 years could have been underestimated by as much as 3 or 4 orders of magnitude. However, because there are large uncertainties in the models used for quantifying the relationship between low doses (that is, less than 10 rem) and the accompanying health impacts, especially under conditions in which the majority of the populations would be exposed at a very low dose rate, the actual collective impact could be small.

On the other hand, impacts to individuals (human intruders) who could move to the storage sites and live close to the degraded facilities could be severe. During the early period (200 to 400 years after the assumed loss of institutional control), acute exposures to external radiation from the spent nuclear fuel and high-level radioactive waste material could result in prompt fatalities. In addition, after a few thousand years onsite shallow aquifers could be contaminated to such a degree that consumption of water from these aquifers could result in severe adverse health effects, including premature death. Uncertainties related to these localized impacts are related primarily to the inability to predict accurately how many individuals could be affected at each of the 77 sites over the 10,000-year analysis period. In addition, the uncertainties associated with localized impacts would exist for potential consequences resulting from disruptive events, both manmade and natural.

Therefore, as listed in Table K-15, uncertainties resulting from future changes in natural phenomena and human behavior that cannot be predicted, process model uncertainties, and dose-effect relationships, taken together, could produce the results presented in Section K.3, overestimating or underestimating the impacts by as much as several orders of magnitude. Uncertainties of this magnitude are typical of predictions of the outcome of complex physical and biological phenomena over long periods. However, these predictions (with their uncertainties) are valuable to the decisionmaking process because they provide insight based on the best information available.

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Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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Appendix L

Floodplain/Wetlands Assessment for the Proposed Yucca Mountain Geologic Repository

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APPENDIX L. FLOODPLAIN/WETLANDS ASSESSMENT FOR THE PROPOSED YUCCA MOUNTAIN GEOLOGIC REPOSITORY

L.1 Introduction

Pursuant to Executive Order 11988, *Floodplain Management*, each Federal agency is required, when conducting activities in a floodplain, to take actions to reduce the risk of flood damage; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. Pursuant to Executive Order 11990, *Protection of Wetlands*, each Federal agency is to avoid, to the extent practicable, the destruction or modification of wetlands, and to avoid direct or indirect support of new construction in wetlands if a practicable alternative exists. Regulations issued by the U.S. Department of Energy (DOE) that implement these Executive Orders are contained in Title 10 of the Code of Federal Regulations (CFR) Part 1022, *Compliance with Floodplain/Wetlands Environmental Review Requirements*.

In 1982, Congress enacted the Nuclear Waste Policy Act in recognition of the national problem created by the accumulation of spent nuclear fuel and high-level radioactive waste at many commercial and DOE sites throughout the country. The Act recognized the Federal government's responsibility to permanently dispose of the Nation's spent nuclear fuel and high-level radioactive waste. By 1986, DOE narrowed the number of potentially acceptable geologic repository sites to three. Then in 1987, Congress amended the Act by redirecting DOE to determine the suitability of only Yucca Mountain in southern Nevada.

If, after a possible recommendation by the Secretary of Energy, the President considers the site qualified for an application to the U.S. Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. If the site designation becomes effective, the Secretary of Energy will submit to the Nuclear Regulatory Commission a License Application for a construction authorization. DOE would also select a rail corridor or a site for an intermodal transfer station, along with its associated route for heavy-haul trucks, among those considered for Nevada in the EIS. Following such a decision, additional field surveys, environmental and engineering analyses, and National Environmental Policy Act reviews would likely be needed regarding a specific rail alignment for the selected corridor. When more specific information becomes available about activities proposed to take place within floodplains and wetlands, DOE will conduct further environmental review in accordance with 10 CFR 1022.

In 1989, DOE published a Notice of Floodplain/Wetlands Involvement (54 *FR* 6318, February 9, 1989) for site characterization studies at Yucca Mountain. These studies are designed to determine the suitability of Yucca Mountain to isolate nuclear waste. A floodplain assessment was prepared (DIRS 104559-YMP 1991, all) and a Statement of Findings was issued by DOE (56 *FR* 49765, October 1, 1991). In 1992, DOE prepared a second floodplain assessment on the cumulative impacts of surface-based investigations and locating part of the Exploratory Studies Facility in the 100-year floodplain of a wash at Yucca Mountain (DIRS 103197-YMP 1992, all). The Statement of Findings for this assessment was published in the Federal Register (57 *FR* 48363, October 23, 1992). Both Statements of Findings concluded that the benefits of locating activities and structures in the floodplains outweigh the potential adverse impacts to the floodplains and that alternatives to these actions were not reasonable.

The Nuclear Waste Policy Act, as amended, requires that a recommendation by the Secretary to the President to construct a repository must be accompanied by a Final EIS. As part of the EIS process, and following the requirements of 10 CFR Part 1022, DOE issued a *Notice of Floodplain and Wetlands Involvement* in the *Federal Register* (64 *FR* 31554, June 11, 1999). The Notice requested comments from the public regarding potential impacts on floodplains and wetlands associated with construction of a potential rail line or a potential intermodal transfer station with its associated route for heavy-haul trucks

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to and in the vicinity of Yucca Mountain, depending on the rail or intermodal alternative selected (Figure L-1). DOE received no comments from the public. This floodplain/wetlands assessment has been prepared in conjunction with the *Notice of Floodplain and Wetlands Involvement*, and in accordance with 10 CFR Part 1022 and was made available to the public as part of the Draft EIS. Several comments were received dealing with this floodplain/wetlands assessment during the public comment period for the Draft EIS. In addition to changes driven by some of these comments, this floodplain/wetlands assessment now includes a statement of findings as Section L.7.

This assessment examines the effects of proposed repository construction and operation and potential construction of a rail line or intermodal transfer station on:

1. Floodplains near the Yucca Mountain site (Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash; there are no delineated wetlands near the Yucca Mountain site), and

2. Floodplains and areas that may have wetlands (for example, springs and riparian areas) along potential rail corridors in Nevada and at intermodal transfer station locations associated with routes for heavy-haul trucks. If DOE selects rail as the mode of spent nuclear fuel and high-level radioactive waste transport in Nevada to the Yucca Mountain site, one of five rail corridors would be selected (Figure L-2). If DOE selects heavy-haul as the mode of transport for spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, one of five heavy-haul truck routes and one of three intermodal transfer station locations would be selected (Figure L-3). A more detailed floodplain/wetlands assessment of the selected rail corridor or route for heavy-haul trucks would then be prepared. This assessment compares what is known about the floodplains, springs, and riparian areas along the five possible rail corridors and at the three intermodal transfer station locations. This assessment does not evaluate potential floodplain or wetlands effects along heavy-haul truck routes because these existing roads should already be designed to meet 100-year floodplain design specifications. If upgrades to existing roads are deemed necessary, a more detailed floodplain/wetlands assessment would be prepared at that time.

Title 10 CFR Part 1022.4 defines a flood or flooding as "*…a temporary condition of partial or complete inundation of normally dry land areas from...the unusual and rapid accumulation of runoff of surface waters...*" Title 10 CFR Part 1022.4 identifies floodplains that must be considered in a floodplain assessment as the *base floodplain* and the *critical-action floodplain*. The base floodplain is the area inundated by a flood having a 1.0 percent chance of occurrence in any given year (referred to as the 100-year floodplain). The critical-action floodplain is the area inundated by a flood having a 0.2 percent chance of occurrence in any given year (referred to as the 500-year floodplain). *Critical action* is defined as any activity for which even a slight chance of flooding would be too great. Such actions could include the storage of highly volatile, toxic, or water-reactive materials. The critical-action floodplain was considered because petroleum, oil, lubricants, and other hazardous materials could be used during the construction of a rail line or road upgrades and because spent nuclear fuel and high-level radioactive waste would be transported across the washes.

Title 10 CFR Part 1022.11 requires DOE to use Flood Insurance Rate Maps or Flood Hazard Boundary Maps to determine if a proposed action would be located in the base or critical-action floodplain. On Federal or state lands where Flood Insurance Rate Maps or Flood Hazard Boundary Maps are not available, DOE is required to seek flood information from the appropriate land-management agency or from agencies with expertise in floodplain analysis. The U.S. Geological Survey was therefore asked by DOE to complete a flood study of Fortymile Wash and its principal tributaries (which include Busted Butte, Drill Hole, and Midway Valley washes) and outline areas of inundation from 100-year and 500-year floods (DIRS 102783-Squires and Young 1984, Plate 1).

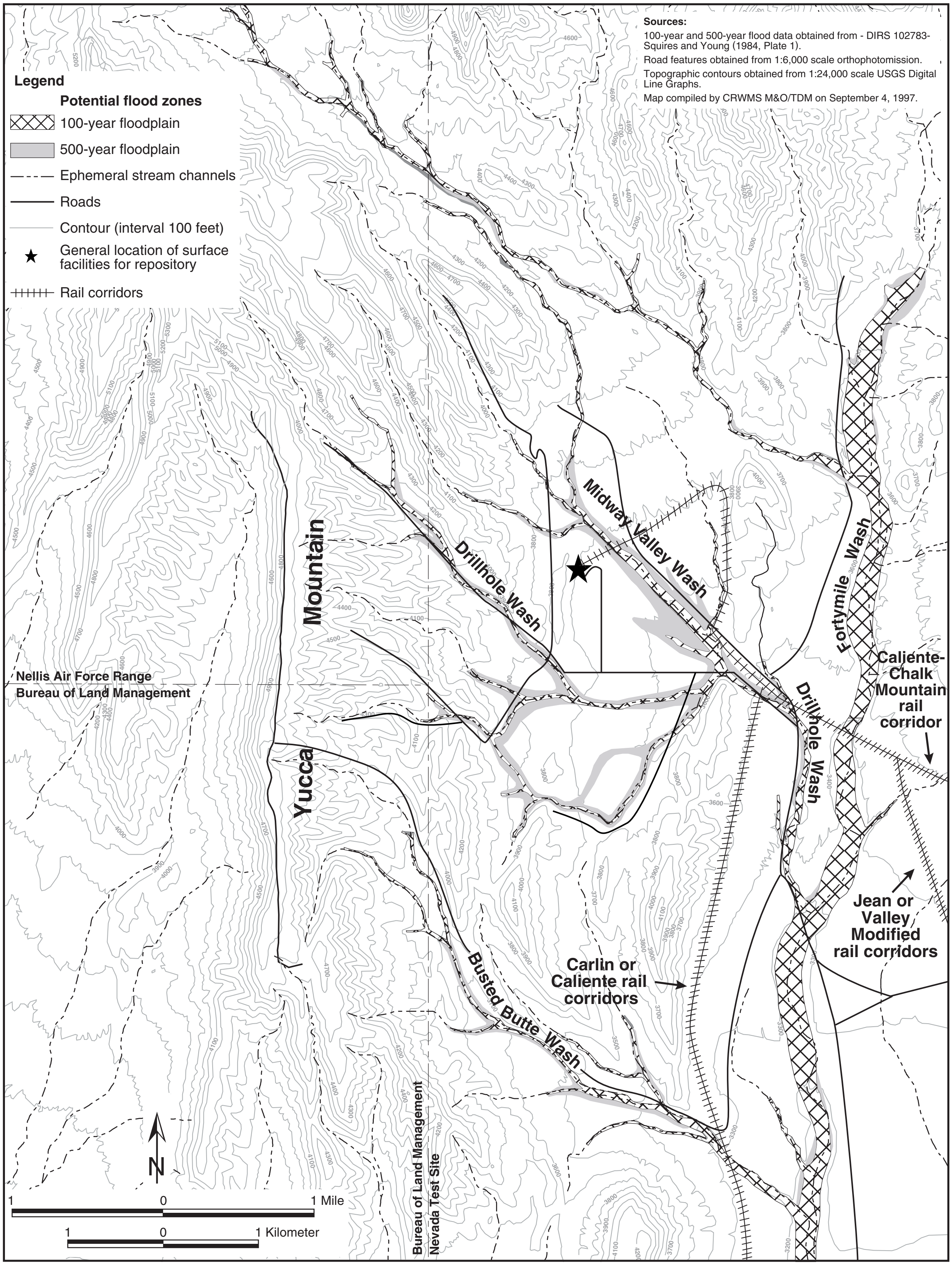

Figure L-1. Yucca Mountain site topography, floodplains, and potential rail corridors.

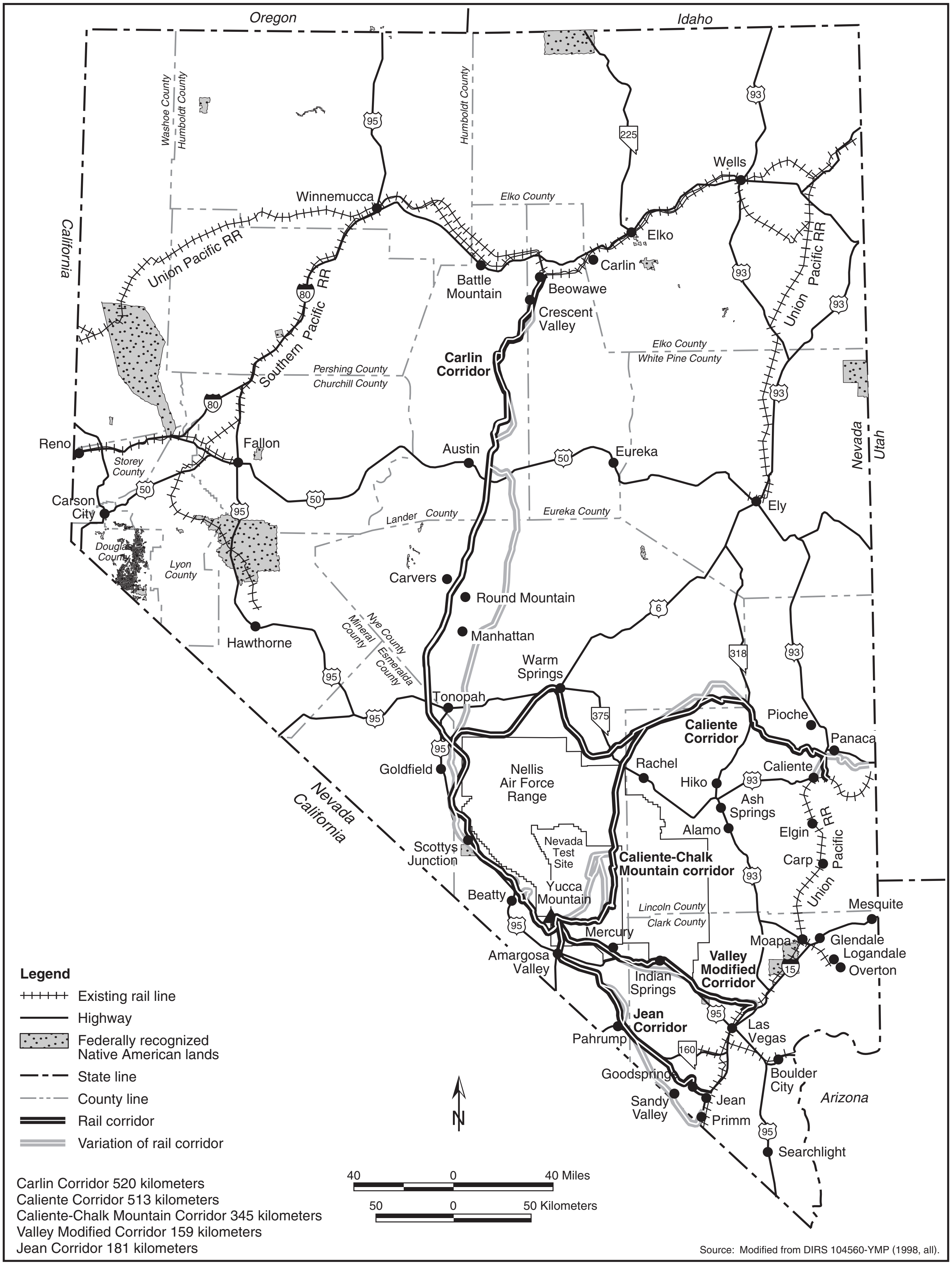

Figure L-2. Potential Nevada rail corridors to Yucca Mountain.

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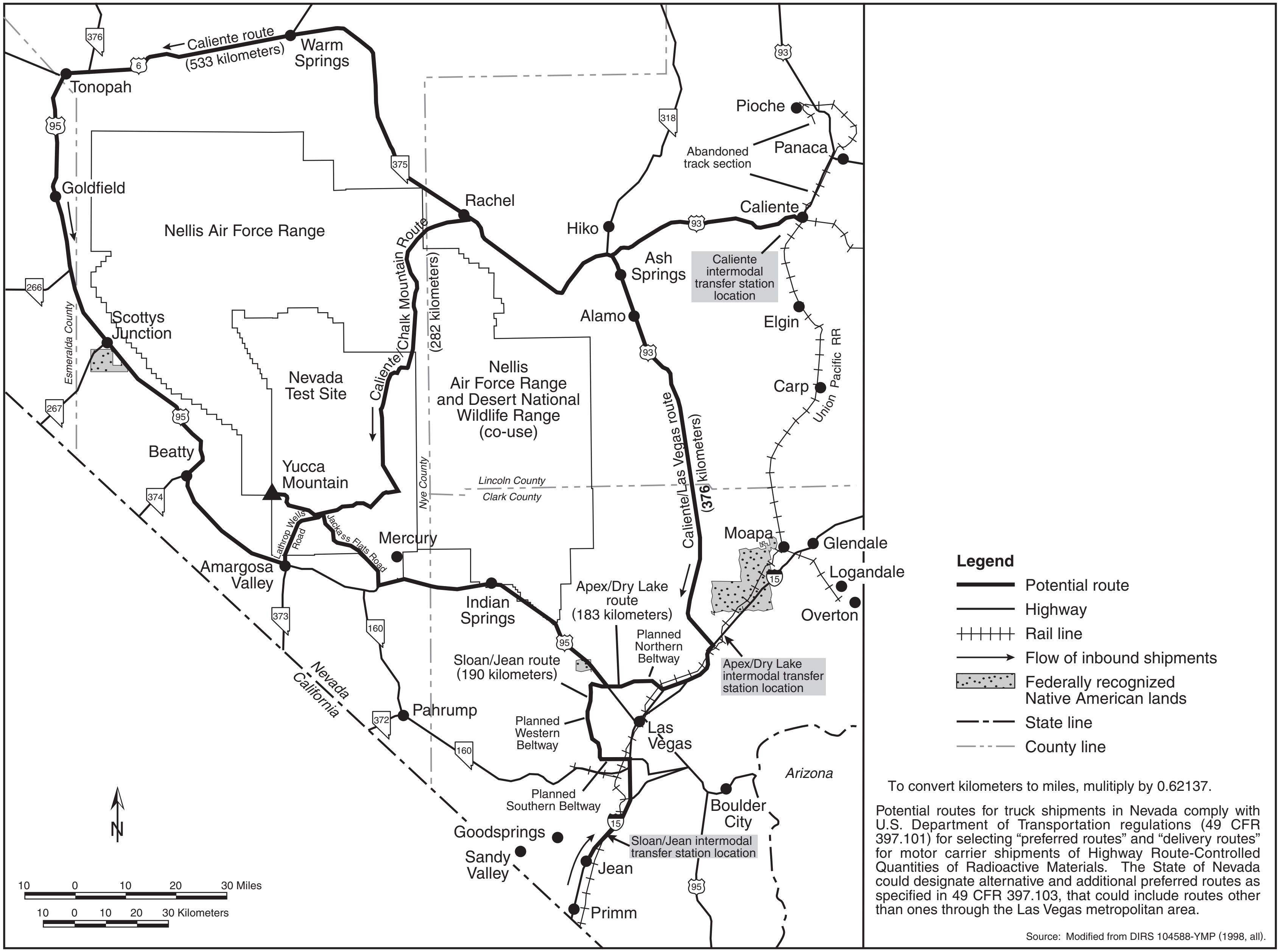

Figure L-3. Potential routes in Nevada for heavy-haul trucks.

Title 10 CFR Part 1022 also requires DOE to determine whether wetlands would be affected by the proposed action and, if necessary, to conduct a wetlands assessment. As required by 10 CFR Part 1022.11(c), DOE examined the following information with regard to possible wetlands in the vicinity of the Yucca Mountain site:

- *U.S. Fish and Wildlife Service National Wetlands Inventory.* Maps from the National Wetlands Inventory do not identify any naturally occurring wetlands in the vicinity of the Yucca Mountain site (DIRS 147930-FWS 1995, all).

- *U.S. Department of Agriculture, Soil Conservation Service Local Identification Maps.* The Soils Conservation Service (now called Natural Resource Conservation Service) has not conducted a soil survey of the Yucca Mountain site. However, DOE and other agencies have conducted comprehensive surveys and studies of soils at the Yucca Mountain site and in the surrounding area. These surveys are summarized in DIRS 104592-CRWMS M&O (1999, pp. 2 to 6). The surveys indicate that there are no naturally-occurring hydric soils at Yucca Mountain.

- *U.S. Geological Survey Topographic Maps.* Topographic maps of the vicinity (for example, DIRS 147932-USGS 1983, all) do not show springs, permanent streams, or other indications of wetlands.

- *State Wetlands Inventories.* There are no State of Nevada wetlands inventories in the vicinity of Yucca Mountain.

- *Regional or Local Government-Sponsored Wetlands or Land-Use Inventories.* DOE has conducted a wetlands inventory of the Nevada Test Site (DIRS 101833-Hansen et al. 1997, p. 1-161). The closest naturally occurring wetlands to Yucca Mountain is on the upper west slope of Fortymile Canyon, 6 kilometers (3.7 miles) north of the North Portal, outside of the proposed repository construction area. In addition, riparian vegetation occurs adjacent to four manmade well ponds east of Yucca Mountain (DIRS 104593-CRWMS M&O 1999, p. 2-14), but these are outside of areas where construction or other proposed actions would occur.

Based on this information, DOE concluded that a wetlands assessment is not required to comply with 10 CFR Part 1022.

L.2 Project Description

If Yucca Mountain is selected as a site to construct a repository, DOE would ship spent nuclear fuel and high-level radioactive waste to the site for a period of about 24 years. For analysis purposes, DOE assumed that spent nuclear fuel and high-level radioactive waste emplacement would begin in 2010. One of five candidate rail corridors leading to the site could be selected in Nevada (Figure L-2). In the vicinity of the Yucca Mountain site the five rail corridors converge to two possible routes. Alternatively, if heavy-haul transport were selected, one intermodal transfer station and one associated route would be identified from the three potential intermodal transfer station locations and five potential routes for heavy-haul trucks (Figure L-3). In the vicinity of the Yucca Mountain site, the potential routes converge to two possible routes that may require upgrades. At greater distances, routes would utilize public roads and existing Nevada Test Site roads to the extent possible.

Some transportation-related actions associated with the DOE proposal would occur in floodplains on the proposed repository site on land the Federal government would manage. Route construction and operation could affect the 100-year and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash in the vicinity of the Yucca Mountain site. This assessment examines the potential floodplain impacts to all four washes although all four might not be affected. The effects on floodplains and areas that may contain wetlands elsewhere in Nevada along the five rail corridors and at the three intermodal station locations associated with heavy-haul transport are examined using available information. When DOE makes a decision whether to use rail or heavy-haul transport, more information would be obtained to support further environmental review.

This section is divided into two parts. Section L.2.1 discusses the proposed action in the vicinity of the Yucca Mountain site including rail access; heavy-haul truck access; and potential construction of an associated rail line, bridge, and roads. Section L.2.2 discusses possible actions elsewhere in Nevada including rail access and intermodal transfer station locations.

L.2.1 PROPOSED ACTIONS AT YUCCA MOUNTAIN

The preliminary layout of surface facilities at the repository is shown on Figure L-1. Except for a possible rail line and roads, no facilities are generally anticipated to be located within either the 100-year or 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, or Midway Valley Wash. The paragraphs below describe the rail line and roads that could affect the floodplains of these washes in the vicinity of the Yucca Mountain site.

DOE has used other flood estimating techniques to evaluate the Proposed Action at Yucca Mountain. As described in Section L.1 and shown in Figure L-1, the U.S. Geological Survey performed the flood study at Fortymile Wash and its principal tributaries that forms the basis for the 100- and 500- year flood inundation levels evaluated in this EIS. DOE used another estimating method, the *probable maximum flood* value methodology [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (DIRS 103071-ANS 1992, all)], to generate maximum flood values for specific segments of washes adjacent to planned Yucca Mountain facilities (DIRS 100530-Blanton 1992, all; DIRS 108883-Bullard 1992, all). The probable maximum flood methodology is a very conservative approach intended to generate the most severe flood value reasonably possible for the location under evaluation, and is larger than any of the other flood values estimated for the site. None of the flood estimates, including those generated for a probable maximum flood, predict water levels high enough to reach the portal entrances to the subsurface facilities. Both the north and south portal entrances to the subsurface facilities were located to be above the probable maximum flood event. However, some of the surface support facilities outside the north portal (in addition to a possible rail line and roads), would be within the level of the probable maximum flood (DIRS 102215-YMP 1995, p. 2-12). DOE would design surface facilities where it would manage radiological materials to ensure their protection against this most severe flood level. The probable maximum flood approach is the method most in use around the world in hydrologic designs for structures critical to public safety, and is required for the design of dam spillways, large detention basins, major bridges, and nuclear facilities.

L.2.1.1 Rail Access

At this time, there is no rail access to the Yucca Mountain site. DOE has identified five candidate rail corridors in Nevada for transporting spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

If DOE selected a rail corridor leading to the Yucca Mountain site from the west and south (either the Carlin or Caliente Corridors), the rail line could cross Busted Butte Wash, Drill Hole Wash just west of its confluence with Fortymile Wash, and Midway Valley Wash (Figure L-1). Cut, fill, drainage culverts or bridges could be used to cross Busted Butte, Drill Hole, and Midway Valley washes. The widths of Busted Butte Wash and Drill Hole Wash (including their floodplains) are about 150 meters (500 feet) each where they would be crossed by the rail line. The width of Midway Valley Wash (including its floodplain) is about 300 meters (1,000 feet) where it could be crossed by the rail line.

If DOE selected a rail corridor leading to the Yucca Mountain site from the east (Caliente-Chalk Mountain, Jean, or Valley-Modified corridors) the rail line could cross approximately 400 meters (1,300 feet) of Fortymile Wash and its associated floodplains. In this case, the rail line could cross the wash on either a bridge (with supports located in the wash) or on a raised rail line that could be constructed in the wash (with appropriately-sized drainage culverts). After crossing Fortymile Wash, the rail line could continue along the east side of Yucca Mountain and cross about 300 meters (1,000 feet) of Midway Valley Wash before arriving at the repository.

L.2.1.2 Heavy-Haul Truck Access

DOE has identified five candidate routes for heavy-haul trucks in Nevada for transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site.

If DOE selected a route leading to the Yucca Mountain site from the west and south, the route could cross Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash (Figure L-1). Cut, fill, drainage culverts or bridges could be used to cross Busted Butte, Drill Hole, and Midway Valley washes.

If DOE selected a route leading to the Yucca Mountain site from the east, the route could cross Fortymile Wash. The route could either cross through the wash or a bridge could be constructed over it. After crossing Fortymile Wash, the route could continue along the east side of Yucca Mountain and could cross Midway Valley Wash before arriving at the repository.

During potential repository operation, some spent nuclear fuel and high-level radioactive waste would be transported to the Yucca Mountain site by legal-weight trucks. These trucks could access Yucca Mountain from the east by crossing Fortymile Wash along the existing road or access Yucca Mountain along the route used by heavy-haul trucks. The legal-weight trucks could then proceed along the east side of Yucca Mountain and cross Midway Valley Wash along the route.

L.2.1.3 Construction

Construction of a candidate rail line near Yucca Mountain as well as upgrading the existing roads for heavy-haul and legal-weight trucks and for access to site facilities in the vicinity would take about 1 year to complete. Existing site roads would be upgraded as needed to provide access between site facilities, including ventilation shafts that would be located to the west of the portal areas. In some cases, new road segments would be necessary to provide the access. The site access roads could go through drainage channels, primarily upper portions of Drill Hole Wash and one of its tributaries to the south (see Figure L-1). Standard construction practices would be used, including the use of explosives and heavy earth-moving equipment. Standard measures would also be used to minimize erosion. Petroleum fuels, oils, lubricants and other hazardous materials would be used during construction, although these materials would be stored outside the 500-year floodplain.

Construction aggregate could be obtained from local borrow pits, but rail-bed ballast would need to be obtained from outside sources. Concrete would be obtained from a nearby concrete batch plant or from a new batch plant that may be built closer to the repository site. Neither the borrow pits nor the concrete batch plant would be located in a floodplain or wetlands. Rock excavated from the subsurface would be stockpiled in the area between the North and South Portals, just south of the primary channel of Drill Hole Wash. The stockpiled rock would be in the area of 100 and 500 year flood zones for a southern tributary to Drill Hole Wash (see Figure L-1).

If DOE decided to build a bridge at the 300- to 450-meter (1,000- to 1,500-foot)-wide Fortymile Wash, it would perform a flood design analysis to determine the optimum span of the structure. Supports for the bridge would be constructed in the floodplain of the wash. If a rail line were constructed across the bottom of Fortymile Wash, extensive earthwork (cut and fill) would be required to maintain the less-than-2-percent grade required for the rail alignment.

L.2.2 POSSIBLE ACTIONS ELSEWHERE IN NEVADA

At this time there is no rail access to Yucca Mountain. This means that material traveling by rail would have to continue to the repository on a new branch rail line or transfer to heavy-haul trucks at an intermodal transfer station in Nevada and then travel on existing highways. DOE is considering construction of *either* a new branch rail line *or* an intermodal transfer station and associated highway improvements. The DOE has identified five candidate rail corridors, each of which has alignment variations (Figure L-2), and three possible locations for an intermodal transfer station associated with heavy-haul trucks (Figure L-3).

For analytical purposes, it is assumed that construction of a rail line in Nevada would take between 40 and 46 months. If a decision were made to proceed with development of a repository, it is likely that the DOE would decide at that time whether to build a rail line or to develop an intermodal transfer station site for heavy-haul waste transport. Should DOE decide to construct a rail line, standard practices for construction of rail lines would be used, including minimizing steep grades, utilizing cut and fill earthwork techniques, and crossing flood-prone areas using culverts or bridges. With respect to flood-prone areas, DOE would generally design rail line features to accommodate 100-year flood levels. However, the final design would be in accordance with standard engineering practices and judgment and economic analysis. The design process would consider a range of flood frequencies and include a cost benefit analysis in the selection of a design frequency (DIRS 106860-AREA 1997, Volume 1, Section 3.3.2.c). Should DOE decide to use a route for heavy-haul trucks, portions of the existing roads used for heavy-haul transport may require upgrades to accommodate the heavy loads.

L.3 Existing Environment

L.3.1 EXISTING ENVIRONMENT AT YUCCA MOUNTAIN

Fortymile Wash is about 150 kilometers (93 miles) long and drains an area of about 810 square kilometers (310 square miles) to the east and north of Yucca Mountain (Figure L-1). The wash continues southward and connects to the Amargosa River. The Amargosa River drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa, California. The mostly-dry river bed extends another 100 kilometers (60 miles) before ending in Death Valley.

Busted Butte and Drill Hole washes drain the east side of Yucca Mountain and flow into Fortymile Wash (Figure L-1; Midway Valley Wash is a tributary to Drill Hole Wash). Busted Butte Wash drains an area of 17 square kilometers (6.6 square miles) and Drill Hole Wash drains an area of 40 square kilometers (15 square miles).

The existing environment at and near Yucca Mountain, including Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash is described in Chapter 3 of the EIS. The information below summarizes several of the more important aspects of the environment that pertain to this floodplain assessment.

L.3.1.1 Flooding

Water flow in the four washes is rare. The arid climate and meager precipitation [about 10 to 25 centimeters (4 to 10 inches) per year at Yucca Mountain] result in quick percolation of surface water into the ground and rapid evaporation. Flash floods, however, can occur after unusually strong summer thunderstorms or during sustained winter precipitation. During these times, runoff from ridges, pediments, and alluvial fans flows into the normally dry washes that are tributary to Fortymile Wash. Estimated peak discharges in Fortymile Wash are 340 cubic meters per second (12,000 cubic feet per second) for the 100-year flood and 1,600 cubic meters per second (58,000 cubic feet per second) for the 500-year flood. Estimated peak discharges in Busted Butte Wash are 40 cubic meters per second (1,400 cubic feet per second) for the 100-year flood and 180 cubic meters per second (6,500 cubic feet per second) for the 500-year flood. Estimated peak discharges in Drill Hole Wash are 65 cubic meters per second (2,300 cubic feet per second) for the 100-year flood and 280 cubic meters per second (10,000 cubic feet per second) for the 500-year flood.

The Nevada Test Site access road to Yucca Mountain crosses Fortymile Wash in the area where it joins Drill Hole Wash. The next nearest manmade structure within Fortymile Wash is U.S. Highway 95, more than 19 kilometers (12 miles) south of the confluence of Drill Hole and Fortymile washes. The portion of the community of Amargosa Valley that was once known as Lathrop Wells is the nearest population center to Yucca Mountain, about 22 kilometers (14 miles) to the south along U.S. 95 and 3.2 kilometers (2 miles) east of Fortymile Wash.

Flooding events in the region are often very localized. A flash flood in one or more of the washes draining to Fortymile Wash, for example, might not result in any notable flow in the much larger Fortymile Wash. In rare cases, however, storm and runoff conditions can be extensive enough to result in flow being present throughout the drainage system. DIRS 155679-Glancy and Beck (1998, all) documented conditions during March 1995 and February 1998 where Fortymile Wash and the Amargosa River flowed simultaneously through their primary channels to Death Valley. The 1995 incident represented the first documented case of this flow condition.

L.3.1.2 Wetlands

There are no springs, perennial streams, hydric soils, or naturally occurring wetlands at Yucca Mountain. There are two manmade well ponds within Fortymile Wash, and two east of that wash, that have riparian vegetation (DIRS 104592-CRWMS M&O 1999, pp. 5 to 6; DIRS 104593-CRWMS M&O 1999, p. 2-14).

L.3.1.3 Biology

Vegetation at and near Fortymile Wash is typical of the Mojave Desert. The mix or association of vegetation in Fortymile Wash, which is dominated by the shrubs white bursage (*Ambrosia dumosa*), creosotebush (*Larrea tridentata*), white burrobush (*Hymenoclea salsola*), and heathgoldenrod (*Ericameria paniculata*), differs somewhat from other vegetation association at Yucca Mountain (DIRS 104589-CRWMS M&O 1998, pp. 5 to 7). No plant species are known to be restricted to the floodplains. In addition, none of the more than 180 plant species known to occur at Yucca Mountain is endemic to the area.

None of the 36 mammal, 27 reptile, or 120 bird species that have been documented at Yucca Mountain are restricted to or dependent on the floodplain. These species all are widespread throughout the region. No amphibians have been found at Yucca Mountain.

The only plant or animal species that has been found at Yucca Mountain that is classified as threatened, endangered, or proposed under the Endangered Species Act is the desert tortoise (*Gopherus agassizii*) which is classified as threatened. Yucca Mountain is at the northern edge of the range of the desert tortoise (DIRS 101915-Rautenstrauch, Brown, and Goodwin 1994, p. 11). Desert tortoises are known to occur within the floodplain of Fortymile Wash, but their abundance there and elsewhere at Yucca Mountain is low compared to other parts of its range farther south and east (DIRS 102869-CRWMS M&O 1997, pp. 6 to 11). Information on the ecology of the desert tortoise population at Yucca Mountain is summarized in DIRS 104593-CRWMS M&O (1999, p. 2-8).

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Four species classified as sensitive by the Bureau of Land Management occur at Yucca Mountain: two species of bats [the long-legged myotis (*Myotis volans*) and the fringed myotis (*Myotis thysanodes*)] (DIRS 104590-CRWMS M&O 1998, p. 11), the western chuckwalla (*Sauromalus obesus obesus*) (DIRS 103159-CRWMS M&O 1998, pp. 22 to 23), and the western burrowing owl (*Speotyto cunicularia hypugaea*) (DIRS 103654-Steen et al. 1997, pp. 19 to 29). These species may occur within the floodplain of Fortymile Wash, but they are not dependent upon habitat there (DIRS 104590-CRWMS M&O 1998, p. 8; DIRS 103159-CRWMS M&O 1998, pp. 22 to 23; DIRS 103654-Steen et al. 1997, pp. 19 to 29).

L.3.1.4 Archaeology

Archaeological surveys have been conducted in Fortymile Wash east of Yucca Mountain. Fortymile Wash was an important crossroad where several trails converged from such distant places as Owens Valley, Death Valley, and the Avawtz Mountains.

L.3.2 EXISTING ENVIRONMENT ELSEWHERE IN NEVADA

The following sections describe the environment along each of the five candidate rail corridors (Figure L-2) and at the three intermodal transfer station locations (Figure L-3). The corridors are about 0.4 kilometer (0.25 mile) wide, and the length of each corridor varies (Table L-1). Table L-2 lists surface-water-related resources along each of the five rail corridors. Table L-3 lists similar information for the corridor variations. The last column of Table L-2 identifies water resources that DOE would avoid by using a specified variation rather than the corresponding section of the corridor. Water resources along the variation that would be "substituted" can be linked from Table L-3. If the same water resource would be close to both the corridor and its variation, it is listed as "Avoided" in Table L-2, but appears in Table L-3 for the variation. Details of each of the corridors and surface-water-related resources are found in DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).

Table L-1. Length of each rail corridor implementing alternative.

Rail corridor	Length	Range with variations
Caliente	513 kilometers (319 miles)	512 to 853 kilometers (318 to 344 miles)
Carlin	520 kilometers (323 miles)	414 to 544 kilometers (257 to 338 miles)
Caliente-Chalk Mountain	345 kilometers (214 miles)	344 to 382 kilometers (214 to 237 miles)
Jean	181 kilometers (112 miles)	181 to 204 kilometers (112 to 127 miles)
Valley Modified	159 kilometers (98 miles)	159 to 163 kilometers (99 to 101 miles)

Table L-4 lists identified 100-year flood zones associated with each rail corridor. The information in this table is from Flood Insurance Rate Maps published by the Federal Emergency Management Agency for Clark, Eureka, Lander, Lincoln, and Nye Counties, Nevada. DOE plotted positions of the rail corridors on the flood maps noting the 100-year flood zones intersected by the corridor centerline and scaling crossing distances. In many cases a single entry in the table represents more than one flood zone encountered in the same general area (for example, in an area of converging drainage channels). As appropriate, the description in the table under the Flood Zone Feature column identifies the inclusion of more than one zone. The last column of Table L-4 identifies if one of the variations along the corridor avoids the specific feature. If it can be avoided (as indicated by a Yes or "Y" in the column), a designation refers to the variation listing in Table L-5. As applicable, the variations in Table L-5 list the flood zones they would cross. In some cases, a flood zone avoided along the corridor would still be crossed at a different location by a variation, and appears on both tables. As indicated in a footnote to Table L-4, the Federal Emergency Management Agency has not published flood maps for all the areas crossed by the rail corridors; the table lists an estimate of the amount of each corridor that is not covered. It does not list Fortymile Wash and other drainage channels near the site of the proposed repository,

Table L-2. Surface-water-related resources along candidate rail corridors[a] (page 1 of 2).

Rail corridor	Distance from corridor (kilometers)[b]	Feature	Avoided by variation[c] (Yes or No)
Caliente, Eccles Option			
Eccles Siding to Meadow Valley Wash	Within	Riparian area/stream – corridor crosses and is adjacent to stream and riparian area in Meadow Valley Wash	Y-1, 2
Meadow Valley to Sand Spring Valley	1.0	Spring – Bennett Spring, 3.2 kilometers southeast of Bennett Pass	N
	0.05 - 2.6	Springs – group of five springs (Deadman, Coal, Black Rock, Hamilton, and one unnamed) east of White River	N
	Within	Riparian/river – corridor parallels (and crosses) the White River for about 10 kilometers. August 1997 survey found river to be mostly underground with ephemeral washes above ground.	N
	0.8	Spring – McCutchen Spring, north of Worthington Mountains	N
Sand Spring Valley to Mud Lake	0.02	Spring – Black Spring, south of Warm Springs	N
Mud Lake to Yucca Mountain	Within - 2.5	Springs – numerous springs and seeps along Amargosa River in Oasis Valley	Y-8
	Within - 0.3	Riparian Area/stream – designated area east of Oasis Valley, flowing into Amargosa River, also riparian area, with persistent water and extensive wet meadows near springs and seeps	Y-8
	0.3 - 1.3	Springs – group of 13 unnamed springs in Oasis Valley north of Beatty	Y-8
Carlin, Big Smoky Valley Option			
Beowawe *to Austin*	0.5	Spring – Tub Spring, northeast of Red Mountain	Y-11
	0.8	Spring – Red Mountain Spring, east of Red Mountain	Y-11
	0.9	Spring – Summit Spring, west of corridor and south of Red Mountain	N
	0.4	Spring – Dry Canyon Spring, west of Hot Springs Point	N
	0.8	Spring – unnamed spring on eastern slope of Toiyabe Range, southwest of Hot Springs Point	N
	1.0	Riparian area – intermittent riparian area associated with Rosebush Creek, in western Grass Valley, north of Mount Callaghan	Y-12
	Within	Riparian/creek – corridor crosses Skull Creek, portions of which have been designated riparian areas	Y-12
	Within	Riparian/creek – corridor crosses intermittent Ox Corral Creek; portions designated as riparian habitat. August, 1997 survey found creek dry with no riparian vegetation present	Y-12

Table L-2. Surface-water-related resources along candidate rail corridors[a] (page 2 of 2).

Rail corridor	Distance from corridor (kilometers)[b]	Feature	Avoided by variation[c] (Yes or No)
Beowawe to Austin (continued)	0.1	Spring – Rye Patch Spring, at north entrance of Rye Patch Canyon, west of Bates Mountain	N
	Within	Riparian area – corridor crosses and parallels riparian area in Rye Patch Canyon	Y-13
	0.7	Spring – Bullrush Spring, east of Rye Patch Canyon	N
Austin to Mud Lake	0.8	Springs – group of 35 unnamed springs, about 25 kilometers north of Round Mountain on east side of Big Smokey Valley	Y-14
	0.6	Riparian area – marsh area formed from group of 35 springs	Y-14
	0.6	Spring – Mustang Spring, south of Seyler Reservoir	Y-14
	0.3	Riparian/reservoir – Seyler Reservoir (seasonal), west of Manhattan	Y-14
Mud Lake to Yucca Mountain		See Caliente Corridor	
Caliente-Chalk Mountain			
Eccles Siding to Meadow Valley		See Caliente Corridor	
Meadow Valley to Sand Spring Valley		See Caliente Corridor	
Sand Spring Valley to Yucca Mountain	1.0	Spring – Reitman's Seep, in eastern Yucca Flat, east of BJ Wye	Y-15, 16
	0.3	Spring – Cane Spring, on north side of Skull Mountain on Nevada Test Site	Y-15
Jean, Wilson Pass Option		None identified	
Valley Modified		None identified	

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).

b. To convert kilometers to miles, multiply by 0.62137.

c. Certain water resources would be avoided by variations. These are identified with a "Y" (yes) and a number representing the specific variation from Table L-3 that avoids the specific resource. Table L-3 identifies the variation by number and shows the water resources associated with each. The same water resource may be in proximity to both the corridor and variation. In such cases, the resource is marked "Avoided" for the corridor here, but will appear on Table L-3 for the variation.

discussed earlier in this document. This is because those washes near the proposed repository site are on the Nevada Test Site, one of the areas not covered by published flood maps.

More detail on each of the rail corridors is provided in Chapter 2, Section 2.1.3.3.2, and Chapter 3, Section 3.2.2. Chapter 6, Section 6.3.2, describes the potential impacts of rail implementing alternatives and Chapter 6, Section 6.3.3 describes the potential impacts of the construction and use of intermodal transfer stations under the heavy-haul truck implementing alternatives.

L.3.2.1 Caliente Corridor

Flooding: The Caliente Corridor, Eccles Option, crosses 352 washes en route to the Yucca Mountain site (DIRS 154961-CRWMS M&O 1998, all). Approximately 12 washes along this route are large enough that bridges would be required to cross them. Based on available Federal Emergency Management Agency flood maps, this corridor would cross nine different 100-year flood zones or flood-zone groups (see Table L-4) between its beginning near Caliente and when it enters the Nevada Test Site. None of the variations applicable to this corridor (Table L-5) would change this number notably. Use of the Crestline

Table L-3. Surface-water-related resources along variations for the rail corridors[a,b] (page 1 of 2).

Variation	Applicable corridor(s)[c]	Distance from corridor (kilometers)[d]	Description
1. Crestline Option	CL/CM	0.3	Spring - Miller Spring south of SR 319 and southeast of Panaca; important water source of game
		1.0	Spring - Miser Spring south of SR 319 and southeast of Panaca
		In	Riparian area/stream - variation crosses Meadow Valley Wash stream and riparian area south of Panaca
2. Caliente Option	CL/CM	In	Riparian area/stream - variation crosses Meadow Valley Wash stream and riparian area south of Caliente
		0.6	Spring - unnamed spring in Caliente
		In	Spring - unnamed spring in Meadow Valley north of Caliente
		0.5	Springs - two unnamed springs in Meadow Valley north of Caliente
3. White River Alternate	CL/CM		None identified - parallels White River further than rail corridor, but not within 1 kilometer
4. Garden Valley Alternate	CL/CM		None identified
5. Mud Lake Alternate	CL/CR		None identified
6. Goldfield Alternate	CL/CR	0.6	Spring - Tognoni Springs northeast of Goldfield
		0.4	Spring - unnamed spring south of Mud Lake and east of U.S. 95
7. Bonnie Claire Alternate	CL/CR		None identified
8. Oasis Valley Alternate	CL/CR	0.5 - 3.0	Springs - numerous springs and seeps along Amargosa River in Oasis Valley
		In - 0.3	Riparian area - designated area east of Oasis Valley, flowing into Amargosa River, also a riparian area, with persistent water and extensive wet meadows near springs and seeps
		0.8 - 1.8	Springs - group of 13 unnamed springs in Oasis Valley north of Beatty
9. Beatty Wash Alternate	CL/CR		None identified
10. Crescent Valley Alternate	CR		None identified
11. Wood Spring Canyon Alternate	CR		None identified
12. Steiner Creek Alternate	CR	In	Riparian area - variation crosses designated riparian area in Water Canyon northeast of Bates Mountain
		In	Riparian/creek - variation crosses Steiner Creek, a designated riparian area. An August 1997 survey found creek dry and lacking riparian vegetation.
13. Rye Patch Alternate	CR	0.1	Riparian area - variation parallels riparian area in Rye Patch Canyon Spring - Bull rush Spring, east of Rye Patch Canyon

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Table L-3. Surface-water-related resources along variations for the rail corridors[a,b] (page 2 of 2).

Variation	Applicable corridor(s)[c]	Distance from corridor (kilometers)[d]	Description
14. Monitor Valley Option	CR	0.7	Spring - unnamed spring east of variation and east of Toquima Range
		0.2	Riparian area - designated riparian area west of variation, northwest of Belmont. An August 1997 survey found area dry and lacking riparian vegetation.
15. Topopah Option	CM	0.6	Spring – Whiterock Spring north of variation, south of Burnt Mountain
15a. Area 4 Alternate	CM		None identified – avoids Whiterock Spring of the Topopah Option
15b. Mine Mountain Alternate	CM		None identified – main portion of option still passes Whiterock Spring
16. Mercury Highway Option	CM		None identified
17. Pahrump Valley Alternate	J		None identified
18. Stateline Pass Option	J		None identified
19. Valley Connection	VM		None identified
20. Sheep Mountain Alternate	VM		None identified
21. Indian Hills Alternate	VM		None identified

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).
b. Rail corridors are identified in Table L-2. Water resources identified in that table that can be avoided by a variation are identified with a number designation which is consistent with the numbering in this table.
c. Rail corridor abbreviations used in the table are defined as follows: CL = Caliente; CM = Caliente-Chalk Mountain; CR = Carlin; J = Jean; and VM = Valley Modified.
d. To convert kilometers to miles, multiply by 0.62137.

Option (number 1 in Table L-5) would decrease the number of flood zones crossed by one, and the other applicable variations would leave the number unchanged or increased by one. As noted in Table L-4, flood map coverage of the Lincoln County portion of this corridor is limited. Additional floodplain definition has not occurred.

Wetlands: At least four springs or groups of springs and three streams or riparian areas that may have associated wetlands are within 0.4 kilometer (0.25 mile) of the Caliente Corridor. However, no field searches or formal delineations of wetlands have been conducted along this route. Black Spring is near the corridor at the north end of the Kawich Range and an unnamed spring is near the corridor at the north end of the North Pahroc Range. A group of springs is in the corridor near the Amargosa River in Oasis Valley. The corridor crosses the Meadow Valley Wash south of Panaca. The corridor also crosses the White River between U.S. Highway 93 and Sand Spring Valley and parallels the river for approximately 10 kilometers (6 miles). That portion of the White River normally is dry. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as riparian area by the Bureau of Land Management (DIRS 104593-CRWMS M&O 1999, p. 3-23). Four of the variation segments (Crestline Option, Caliente Option, Goldfield Alternate, and Oasis Valley Alternate) along the Caliente Corridor would affect the number of, or distance to, associated water resources. Using the Crestline Option, Caliente Option, or Goldfield Alternate would add one spring within 0.4 kilometer (0.25 mile) of the corridor. The Oasis Valley Alternate is close to the same water resources as the corresponding portion of the Caliente Corridor, but it would be farther from two groups of springs near the Amargosa River.

Biology: The desert tortoise is the only threatened or endangered species found along the Caliente Corridor. The southern 50 kilometers (30 miles) of this corridor is within desert tortoise habitat. This area is not designated as critical habitat and the abundance of tortoises in the area is low (DIRS 104593-CRWMS M&O 1999, p. 3-23). Southwestern willow flycatchers (*Empidonax traillii extimus*), an

Table L-4. 100-year flood zones crossed by candidate rail corridors[a] (page 1 of 2).

Rail corridor and segment[b]	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (Yes or No)
Caliente, Eccles Option			
Eccles Siding to Meadow Valley Wash	0.2[e]	Clover Creek (intermittent)	Y-1
	0.8[e]	Meadow Valley Wash (wet)	Y-1,2
Meadow Valley Wash to Sand Spring Valley	0.5[e]	White River (intermittent)	N
Sand Spring Valley to Mud Lake	1.1	Unnamed drainage gully in East/Central Nye County; crosses twice (dry)	N
	17.5	Mud Lake basin and drainage tributaries (normally dry)	N
Mud Lake to Yucca Mountain	0.8	Unnamed washes to the north and south of Ralston (dry)	N
	0.3	Tolicha Wash	Y-7
	1.1	Amargosa River (wet in sections, intermittent in others)	Y-8
	0.1	Beatty Wash	Y-9
Carlin, Big Smoky Valley Option			
Beowawe to Austin	4.0	Flood zone associated with Coyote Creek drainage (dry)	N
	1.6	Indian Creek (dry) and unnamed wash to the south	Y-10
	0.9	Unnamed Callaghan tributary, Skull and Callaghan Creeks (intermittent)	Y-12
	0.1	Rye Patch Canyon Creek (intermittent)	Y-13,14
	1.4	Simpson Park Canyon Creek (intermittent) and Canyon Creek drainage (intermittent)	Y-13,14
	1.4	Canyon Creek and Canyon Creek drainage (intermittent)	Y-14
Austin to Mud Lake	0.3	Peavine Creek tributary (intermittent)	Y-14
Mud Lake to Yucca Mountain		See Caliente Corridor	
Caliente-Chalk Mountain			
Eccles Siding to Meadow Valley to Sand Spring Valley		See Caliente Corridor	
Sand Spring Valley to Yucca Mountain	--[f]	Not available	
Jean,[d] Wilson Pass Option			
Jean to Yucca Mountain	0.6	Three tributaries leading to Roach Lake (intermittent)	Y-18
	0.7	Lovell Wash with drainage (intermittent)	Y-18
	0.4	Two unnamed washes northwest of Lovell Wash	N
	4.1	Peak Springs Alluvial Fan (dry)	N
	1.9	Wheeler Wash (dry)	N
	0.3	Wash drainage leading to Alkali Flats (dry)	N
	0.1	Rock Valley Wash (intermittent)	N

Table L-4. 100-year flood zones crossed by candidate rail corridors[a] (page 2 of 2).

Rail corridor and segment[b]	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (Yes or No)
Valley Modified			
Dry Lake to Yucca Mountain	0.1[f]	Unnamed creek northwest of the City of Las Vegas (intermittent)	N
	1.2[e]	Drainage (projected) west of Indian Springs Air Force Auxiliary Base (intermittent)	Y-21

a. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Clark, Eureka, Lander, Lincoln, and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).

b. Percentage of missing rail corridor information.
   1. *Caliente* - About 47 percent not available on Federal Emergency Management Agency maps, mostly due to limited coverage in Lincoln County and the Nevada Test Site.
   2. *Carlin* - About 17 percent is not available on Federal Emergency Management Agency maps, mostly due to limited coverage in Esmeralda County and Nevada Test Site.
   3. *Caliente-Chalk Mountain* – About 91 percent is not available on Federal Emergency Management Agency maps, mostly due to limited coverage in Lincoln County, the Nellis Air Force Range, and the Nevada Test Site.
   4. *Jean* - About 10 percent is not available on Federal Emergency Management Agency maps due to the portion of the route in the Nevada Test Site.
   5. *Valley Modified* - Approximately 25 percent is not available on Federal Emergency Management Agency maps due to the portion of the route in the Nellis Air Force Range, and the Nevada Test Site.

c. To convert kilometers to miles, multiply by 0.62137.

d. Certain 100-year flood zones can be avoided by corridor variations. These are identified with a "Y" (yes) and a number representing the specific variation(s) from Table L-5 that avoids the specific flood zone. The same flood zone may be crossed by both the rail corridor and a variation at different locations. In such cases, the feature will be marked "Avoided" for the rail corridor here, but will appear again on Table L-5 for the variation.

e. Projected from limited data. Specific area not covered by Federal Emergency Management Agency maps; values were extrapolated from the closest maps.

f. Limited information due to the Nevada Test Site and/or the Nellis Air Force Range.

endangered species, have been observed in dense stands of riparian vegetation in Lincoln County, but there is no suitable habitat for this species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13). Three other species (Meadow Valley Wash speckled dace [*Rhinichthys osculus* ssp.], Meadow Valley Wash desert sucker [*Catostomus clarki* ssp.], and Nevada sanddune beardtongue) classified as sensitive by the Bureau of Land Management or as protected by Nevada have been found along the Caliente Corridor. This rail corridor crosses approximately 14 areas designated as game habitat and one area classified as waterfowl habitat (DIRS 104593-CRWMS M&O 1999, p. 3-23). Two of these species, the speckled dace and desert sucker, are restricted to the floodplain of the Meadow Valley Wash. The designated waterfowl habitat also is generally restricted to the floodplain of Meadow Valley Wash and adjacent wetlands.

Archaeology: There are 97 archaeological sites that have been recorded along the Caliente Corridor (DIRS 104997-CRWMS M&O 1999, Table 3, p. 59).

L.3.2.2 Carlin Corridor

Flooding: The Carlin Corridor, Big Smoky Valley Option, crosses 273 washes en route to the Yucca Mountain site (DIRS 154961-CRWMS M&O 1998, all). Approximately 10 washes along this route are large enough that bridges would be required to cross them. According to the Federal Emergency Management Agency flood map data summarized in Table L-4, this corridor would cross 11 different 100-year flood zones or flood zone groups before entering the Nevada Test Site. Eight of the 10 variations applicable to this corridor (see Table L-5) would change the number of flood zones crossed, but with one exception, changes would be up or down by only one. The exception would be the Monitor

Table L-5. 100-year flood zones crossed by unique segments of corridor variations[a,b] (page 1 of 2).

Variation	Corridor(s)[c]	Crossing distance (kilometers)[d]	Flood zone feature(s)
1. Crestline Option	CL/CM	0.8	Crosses Meadow Valley Wash (wet)
2. Caliente Option	CL/CM	0.8	Crosses Meadow Valley Wash (wet)
		0.2	Crosses Clover Creek (intermittent)
		0.9	Crosses Meadow Valley Wash (wet) three times, runs adjacent to Meadow Valley Wash, passes in and out of flood zone
3. White River Alternate	CL/CM	None	North of the unvaried corridor
4. Garden Valley Alternate	CL/CM	None	North of the unvaried corridor
5. Mud Lake Alternate	CL/CR	3.1	Crosses a larger amount of the Mud Lake flood zone (3.1 kilometers versus 1.8 kilometers for the unvaried corridor section)
6. Goldfield Alternate	CL/CR	None	West of unvaried corridor
7. Bonnie Claire Alternate	CL/CR	1.3	Crosses an unnamed wash south of Ralston
		0.7	Crosses Tolicha Wash (intermittent)
8. Oasis Valley Alternate	CL/CR	1.0	Crosses Amargosa River (wet in segments, intermittent in others)
9. Beatty Wash Alternate	CL/CR	0.1	Crosses Beatty Wash (intermittent)
10. Crescent Valley Alternate	CR	2.0	Crosses Indian Creek (intermittent)
		3.2	Crosses an unnamed wash to the south
11. Wood Spring Canyon Alternate	CR	None	West of the unvaried corridor
12. Steiner Creek Alternate	CR	4.9	Crosses Callaghan and Canyon Creeks (intermittent)
13. Rye Patch Alternate	CR	1.4	Crosses Canyon Creek and Canyon Creek drainage (intermittent)
14. Monitor Valley Option[e]	CR	0.6	Crosses Mosquito Creek (intermittent)
		0.5	Crosses Corcoran Creek and Meadow Creek (intermittent)
		1.5	Crosses Meadow Creek drainage (dry)
		0.6	Crosses Hunts Canyon Creek (intermittent)
		0.2	Crosses Willow Creek (intermittent)
		2.0	Crosses drainage areas approaching Mud Lake (dry)
		5.7	Crosses drainage areas approaching Mud Lake (dry)
		4.8	Crosses Mud Lake drainage (dry)
15. Topopah Option	CM	--[f]	Adjacent to Caliente-Chalk Mountain Corridor
16. Mercury Highway Option	CM	--[f]	Adjacent to Caliente-Chalk Mountain Corridor
17. Pahrump Valley Alternate	J	None	Northeast of unvaried corridor
18. Stateline Pass Option	J	0.4	Crosses two tributaries to Roach Lake (dry)
		0.8	Crosses Potasi Wash, an unnamed wash and Lovell Wash drainage
		1.1	Crosses four unnamed washes and Peak Springs Fan (intermittent)

Table L-5. 100-year flood zones crossed by unique segments of corridor variations[a,b] (page 2 of 2).

Variation	Corridor(s)[c]	Crossing distance (kilometers)[d]	Flood zone feature(s)
19. Valley Connection	VM	None	At the origin of the rail corridor
20. Sheep Mountain Alternate	VM	None	North of the rail corridor
21. Indian Hills Alternate	VM	None	South of the rail corridor

a. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Clark, Eureka, Lander, Lincoln, and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).
b. Rail corridors are identified in Table L-4. Flood zones identified in that table that can be avoided by a variation are identified with a number designation that is consistent with the numbering in this table.
c. Rail corridor abbreviations: CL = Caliente; CM = Caliente-Chalk Mountain; CR = Carlin; J = Jean; VM = Valley Modified.
d. To convert kilometers to miles, multiply by 0.62137.
e. The Monitor Valley Option and the Goldfield Connector were combined since the flood zone crossings were approximately the same distances and the final flood zone crossing distance percentages are 8 percent for all Monitor Valley variations.
f. No information available on Federal Emergency Management Agency maps.

Valley Option (number 14 in Table L-5) which would increase the number of 100-year flood zones crossed by four. Table L-4 lists more 100-year flood zones for the Carlin Corridor than for any of the other corridors. This might be due, in part, to the fact that a large portion of the Carlin Corridor is covered by flood maps. Additional floodplain definition has not occurred.

Wetlands: There are at least three springs or groups of springs, four streams designated as riparian areas by the Bureau of Land Management, and one reservoir that may have associated wetlands within 0.4 kilometer (0.25 mile) of the Carlin Corridor. However, no field searches or formal delineations of wetlands have been conducted along this route. Rye Patch Spring is on the edge of the corridor at the south end of the Simpson Park Mountains, and a group of springs is in the corridor near the Amargosa River in Oasis Valley. Seyler Reservoir is less than 0.3 kilometer (0.2 mile) from the corridor in the south end of Big Smoky Valley. There are three riparian areas (Skull and Ox Corral creeks, and Rye Patch Canyon) along the section of the route between Beowawe and Austin at the south end of Grass Valley. Ox Corral creek, at the south end of Grass Valley, is ephemeral and has little or no riparian vegetation where the route crosses it. The corridor crosses the Amargosa River in the northern Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management (DIRS 104593-CRWMS M&O 1999, pp. 3-25 to 3-26). Five of the variations (Oasis Valley, Steiner Creek, Rye Patch and Goldfield Alternates, and Monitor Valley Option) would affect the number of, or distance to, water resources along the Carlin Corridor. Changes associated with the Oasis Valley and Goldfield Alternates are covered above in the Caliente Corridor discussion. The Rye Patch Alternate would involve no changes to water resources in, or within 0.4 kilometer (0.25 mile) of, the Carlin Corridor, but would parallel the riparian area in Rye Patch Canyon rather than cross it. The Steiner Creek Alternate would avoid two riparian areas, but another two would be within this corridor variation. The Monitor Valley Option would represent a major change in the corridor but, with respect to water resources within 0.4 kilometer, it would avoid only Seyler Reservoir and would add a designated riparian area northwest of Belmont.

Biology: The desert tortoise is the only threatened or endangered species found along the Carlin Corridor. The southern 50 kilometers (30 miles) of this corridor is within desert tortoise habitat. This area is not designated as critical habitat and the abundance of tortoises in the area is low (DIRS 104593-CRWMS M&O 1999, p. 3-25). Three other species (ferruginous hawk [*Buteo regalis*], San Antonio pocket gopher [*Thomomys umbrinus curtatus*], and Nevada sand dune beardtongue [*Penstemom arenarius*]) classified as sensitive by the Bureau of Land Management or as protected by the State of Nevada have been found along the Carlin Corridor. Additionally, the rail corridor crosses approximately 7 areas designated as game habitat by the Bureau of Land Management (DIRS 104593-CRWMS M&O

1999, p. 3-25). None of these species or game habitats are restricted to floodplains or areas that may have wetlands.

Archaeology: There are 110 archaeological sites that have been recorded along the Carlin Corridor (DIRS 104997-CRWMS M&O 1999, Table 3, p. 59).

L.3.2.3 Caliente-Chalk Mountain Corridor

Flooding: The Caliente-Chalk Mountain Corridor crosses 281 washes en route to the Yucca Mountain site (DIRS 154961-CRWMS M&O 1998, all). Approximately five washes along this route are large enough that bridges would be required to cross them. Based on the Federal Emergency Management Agency flood map data summarized in Table L-4, this corridor would cross only three different 100-year flood zones or flood zone groups before entering the Nellis Air Force Range. Two of the four alternative segments applicable to this corridor (see Table L-5) would change the number of flood zones crossed, but changes would be up or down by only one. The low number of flood zones identified for the Caliente-Chalk Mountain Corridor should be qualified by the fact that a great majority of this corridor, as noted in Table L-4, is not covered by flood maps. This is due to limited coverage in Lincoln County and no coverage inside the Nellis Air Force Range and the Nevada Test Site. Additional floodplain definition has not occurred.

Wetlands: At least one spring or group of springs and two streams that may have associated wetlands occur within 0.4 kilometer (0.25 mile) of the Caliente-Chalk Mountain Corridor. However, no field searches or formal delineations of wetlands have been conducted along this route. An unnamed spring is near the corridor at the north end of the North Pahroc Range. The corridor crosses Meadow Valley Wash south of Panaca. The corridor crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 10 kilometers (6 miles). That portion of the White River normally is dry.

Biology: The desert tortoise is the only threatened or endangered species found along the Caliente-Chalk Mountain Corridor. The southern 40 kilometers (25 miles) of this corridor is within desert tortoise habitat. This area is not designated as critical habitat and the abundance of tortoises in the area is low (DIRS 104593-CRWMS M&O 1999, p. 3-27). Southwestern willow flycatchers, an endangered species, have been observed in dense stands of riparian vegetation in Lincoln County, but there is no suitable habitat for this species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13). Four species (Meadow Valley Wash speckled dace, Meadow Valley Wash desert sucker, Ripley's springparsley [*Cymopterus ripleyi* var. *saniculoides*], and largeflower suncup [*Camissonia megalantha*]) classified as sensitive by the Bureau of Land Management or protected by Nevada have been found in the Caliente-Chalk Mountain Corridor. This rail corridor crosses approximately six areas designated as game habitat and one area of waterfowl habitat (DIRS 104593-CRWMS M&O 1999, p. 3-27). Two of these sensitive species, the speckled dace and desert sucker, are restricted to the floodplain of the Meadow Valley Wash. The designated waterfowl habitat also is generally restricted to the floodplain of Meadow Valley Wash and adjacent wetlands.

Archaeology: There are 100 archaeological sites that have been recorded along the Caliente-Chalk Mountain route Corridor (DIRS 104997-CRWMS M&O 1999, Table 3, p. 59).

L.3.2.4 Jean Corridor

Flooding: The Jean Corridor, Wilson Pass Option, crosses 89 washes en route to the Yucca Mountain site (DIRS 154961-CRWMS M&O 1998, all). Approximately five washes along this route are large enough that bridges would be required to cross them. This corridor would cross seven different 100-year flood zones or flood zone groups (see Table L-4) before entering the Nevada Test Site. Use of the

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Stateline Pass Option to this corridor (see Table L-5) would increase the number of flood zones crossed by one. Use of the Pahrump Valley Alternate would result in no change. Federal Emergency Management Agency flood map coverage of this corridor is the highest in terms of percentage of any of the rail corridors. Additional floodplain definition has not occurred.

Wetlands: No springs, perennial streams, or riparian areas that may have associated wetlands have been identified within 0.4 kilometer (0.25 mile) of the Jean Corridor or its variations (DIRS 104593-CRWMS M&O 1999, p. 3-29). However, no field searches or formal delineations of wetlands have been conducted along this route.

Biology: The desert tortoise is the only threatened or endangered species found along the Jean Corridor. This entire corridor, including its variations, is within desert tortoise habitat, but does not cross any areas designated as critical habitat. The abundance of desert tortoises is low along most of the rail corridor, although there is a higher abundance along some portions in Ivanpah, Goodsprings, Mesquite, and Pahrump valleys (DIRS 104593-CRWMS M&O 1999, p. 3-28). One species, the pinto beardtongue (*Penstemon bicolor* spp.) that is classified as sensitive by the Bureau of Land Management has been found within the corridor. This rail corridor crosses approximately 10 areas designated as game habitat by the Bureau of Land Management (DIRS 104593-CRWMS M&O 1999, p. 3-28). None of these species or game habitats are restricted to floodplains or areas that may have wetlands.

Archaeology: Six archaeological sites have been recorded along the Jean Corridor (DIRS 104997-CRWMS M&O 1999, Table 3, p. 59).

L.3.2.5 Valley Modified Corridor

Flooding: The Valley Modified Corridor crosses 95 washes en route to the Yucca Mountain site (DIRS 154961-CRWMS M&O 1999, pp. 3 to 4). Approximately three washes along this route are large enough that bridges would be required to cross them. Based on the Federal Emergency Management Agency flood map data summarized in Table L-4, this corridor would cross only two different 100-year flood zones or flood zone groups before entering the Nevada Test Site. Of the three variations to this corridor (see Table L-5), the Indian Hills Alternate (number 21 in Table L-5) would decrease the number of flood zones to one; the other two variations would have no change. Flood map coverage of the Valley Modified Corridor is relatively good at about 75 percent. Additional floodplain definition has not occurred.

Wetlands: No springs, perennial streams, or riparian areas that may have associated wetlands have been identified within 0.4 kilometer (0.25 mile) of the Valley Modified Corridor or its variations (DIRS 104593-CRWMS M&O 1999, pp. 3-29 to 3-30). However, no field searches or formal delineations have been conducted along this route.

Biology: The desert tortoise is the only threatened or endangered species found along the Valley Modified Corridor. This entire corridor, including its variations, is within desert tortoise habitat, but does not cross any areas designated as critical habitat. The abundance of desert tortoises is low along this rail corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29). Two plant species (Parish's scorpionweed [*Phacelia parishii*] and Ripley's springparsley) classified as sensitive by the Bureau of Land Management have been found in the rail corridor. None of these species are restricted to floodplains or areas that may have wetlands. The Valley Modified Corridor does not cross any Bureau of Land Management-designated game habitat (DIRS 104593-CRWMS M&O 1999, p. 3-29).

Archaeology: Nineteen archaeological sites have been recorded along the Valley Modified Corridor (DIRS 104997-CRWMS M&O 1999, Table 3, p. 59).

L.3.2.6 Caliente Intermodal Transfer Station

Flooding: The two proposed sites for the Caliente intermodal transfer station are located in the Meadow Valley Wash south of Caliente. Both areas are outside the inundation boundary of the 100-year floodplain, but within the boundary of the 500-year floodplain.

Wetlands: Part of the proposed station location is moist during at least some portions of the year. There are no springs on the site; there are springs adjacent to the site and some areas within the site have soils and plant species indicative of wetlands. Many of these moist areas are believed to be the result of irrigation with treated effluent from the wastewater treatment facility within the site, but some might qualify as wetlands or other waters of the United States if they are the result of outflow from nearby springs or the adjacent Meadow Valley Wash. The adjacent perennial stream and riparian habitat along Meadow Valley Wash also might be classified as wetlands, although no formal delineation of wetlands has been conducted for this proposed activity (DIRS 104593-CRWMS M&O 1999, p. 3-35).

Biology: No game habitat, threatened or endangered species, or species classified as sensitive by the Bureau of Land Management or protected by Nevada occur within the proposed station location (DIRS 104593-CRWMS M&O 1999, p. 3-35). Although the Federally endangered Southwestern willow flycatcher has been detected in Meadow Valley Wash, there is no habitat for this species on this site (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

Archaeology: Four archaeological sites have been recorded at the Caliente intermodal transfer station site (DIRS 104997-CRWMS M&O 1999, Table 2, p. 32).

L.3.2.7 Apex/Dry Lake Intermodal Transfer Station

Flooding: The three proposed sites for the Apex/Dry Lake intermodal transfer station are outside the 100-year and 500-year floodplains.

Wetlands: There are no springs or riparian areas within the proposed station location (DIRS 104593-CRWMS M&O 1999, p. 3-36).

Biology: The only resident threatened or endangered species at this site is the desert tortoise. The abundance of desert tortoises in Dry Lake Valley generally is low, although some areas there have a higher abundance. One plant species, Geyer's milkvetch (*Astragalus geyeri triquetrus*), classified as sensitive by the Bureau of Land Management has been found in the proposed location. Neither of these species are restricted to floodplains or wetlands. No game habitat has been designated there (DIRS 104593-CRWMS M&O 1999, p. 3-36).

Archaeology: Two archaeological sites have been recorded at the Apex/Dry Lake intermodal transfer station site (DIRS 104997-CRWMS M&O 1999, Table 2, p. 32).

L.3.2.8 Sloan/Jean Intermodal Transfer Station

Flooding: The southernmost proposed site for the Sloan/Jean intermodal transfer station is located in the same general area as a 100-year flood inundation zone. The middle site is not in an inundation zone and is outside the 500-year floodplain. The northernmost proposed site is in an area with no printed Federal Emergency Management Agency map and it is outside the 500-year floodplain.

Wetlands: There are no springs or riparian areas within the proposed station location (DIRS 104593-CRWMS M&O 1999, p. 3-36).

Biology: The only resident threatened or endangered species at this site is the desert tortoise. The abundance of desert tortoises in Ivanpah Valley generally is moderate to high, relative to other areas within the range of this species in Nevada. One plant species, pinto beardtongue, classified as sensitive by the Bureau of Land Management has been found in the proposed location. Neither of these species are restricted to floodplains or wetlands. No game habitat has been designated there (DIRS 104593-CRWMS M&O 1999, pp. 3-36 to 3-37).

Archaeology: Seven archaeological sites have been recorded at the Sloan/Jean intermodal transfer station site (DIRS 104997-CRWMS M&O 1999, Table 2, p. 32).

L.4 Floodplain/Wetlands Effects

According to 10 CFR 1022.12(a)(2), a floodplain assessment is required to discuss the positive and negative, direct and indirect, and long- and short-term effects of the proposed action on the floodplain and/or wetlands. In addition, the effects on lives and property, and on natural and beneficial values of floodplains must be evaluated. For actions taken in wetlands, the assessment should evaluate the effects of the proposed action on the survival, quality, and natural and beneficial values of the wetlands. If DOE finds no practicable alternative to locating activities in floodplains or wetlands, DOE will design or modify its actions to minimize potential harm to or in the floodplains and wetlands. The floodplains that are assessed herein are those areas of normally dry washes that are temporarily and infrequently inundated from runoff during 100-year or 500-year floods.

L.4.1 FLOODPLAIN/WETLANDS EFFECTS NEAR YUCCA MOUNTAIN

DOE has not determined if rail casks will be transported in Nevada by heavy-haul trucks on existing highways or whether to construct a branch rail line to bring the spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. Near Yucca Mountain, however, it is possible that each of the four washes could be affected if a rail line and a road were to access the Yucca Mountain site from different directions. Because of this uncertainty, this assessment examines the configurations that would cause the most disturbances to the four washes and their floodplains, as follows:

- Potential construction of a heavy-haul-capable road west of Fortymile Wash that crosses Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash. Cut, fill, and drainage culverts could be used to cross Busted Butte and Drill Hole washes. A bridge could be constructed over Midway Valley Wash. Heavy-haul trucks carrying spent nuclear fuel and high-level radioactive waste could travel along this road to the repository.

- Potential construction of a raised rail line through Fortymile Wash with appropriately-sized drainage culverts. The rail line could join the route for heavy-haul trucks north of Drill Hole Wash and cross Midway Valley Wash on a separate rail-bridge before entering the repository. Trains carrying spent nuclear fuel and high-level radioactive waste could travel along the rail line to the repository.

- Potential upgrading of the existing road that crosses Fortymile Wash with appropriately-sized drainage culverts. The road could be used by legal-weight trucks to transport spent nuclear fuel and high-level radioactive waste to the repository, as well as transporting various types of hazardous and non-hazardous materials to and from the repository.

Construction in the washes would reduce the area through which floodwaters naturally flow. During large floods, bodies of water could develop on the upstream side of each of the crossings and slowly drain through culverts. Such floods, however, would not increase the risk of future flood damage, increase the impact of floods on human health and safety, or harm the natural and beneficial values of the floodplains because there are no human activities or facilities upstream or downstream that could be affected. A sufficiently large flood in Fortymile Wash could create a temporary large lake up-stream of the raised rail line and the legal-weight road. The water would slowly drain through culverts. If the flood occurred quickly and was sufficiently large, water would flow over the rail line and roads and continue downstream. Some damage to the rail line and the roads would be expected, but neither structure would increase the risk of future flood damage, increase the impact of floods on human health and safety, or harm the natural and beneficial values of the floodplains because there are no human activities or facilities downstream that could be affected.

During and after each flood, a large amount of sediment would accumulate on the up-stream side of each crossing. Periodically, this material would have to be removed so that future floods would have sufficient space to accumulate, rather than overflow the structures during successively smaller floods. This material would, when deemed necessary, be removed by truck and disposed of appropriately. Under natural conditions this sediment would have continued downstream and been deposited as the floodwaters receded. Compared to the total amount of sediment that is moved by the flood water along the entire length of the washes, the amount trapped behind the crossings would be small.

During a 100-year or 500-year flood, there would be no preferred channels; all channels across the entire width of each wash would be filled with water (Figure L-1). Therefore, the manmade crossings would not cause preferential flow in a particular channel or alter the velocity or direction of flow on the floodplains.

Potential construction of a route for heavy-haul trucks or rail line would require the removal of desert vegetation in the washes and the disturbance of soil and alluvium. These actions could adversely impact wildlife habitat and individuals, especially the desert tortoise, which is designated as threatened by the Fish and Wildlife Service. Prior to any construction, a biological survey would be conducted to locate and remove tortoises that are in the path of construction and other mitigation measures would be conducted as identified by the Fish and Wildlife Service during consultations under the Endangered Species Act for this action.

Construction in the floodplains could also affect unidentified cultural resources that may be present. Prior to any construction, archaeologists would survey the area following the procedure in DOE's Programmatic Agreement with the Advisory Council on Historic Preservation (DIRS 104558-DOE 1988, p. 5). DOE would avoid such sites if possible or, if it was not possible, would conduct a data recovery program of the sites in accordance with applicable regulatory requirements and input from official tribal contact representatives and document the findings. The artifacts from and knowledge about the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.

Potential indirect impacts on flora and fauna include increased emissions of fugitive dust, elevated noise levels, and increased human activities. Emissions of fugitive dust would be short-term and would not be expected to significantly affect vegetation or wildlife. Likewise, no significant long-term impacts to wildlife are expected from the temporary increase in noise during construction. Wildlife displaced during construction would probably return after construction was completed.

There are no perennial sources of surface water at or downstream from the Yucca Mountain site that would be affected by the use of a route for heavy-haul trucks or the construction of a rail line. Two small well ponds with some riparian vegetation occur in Fortymile Wash downstream of the point where Drill Hole Wash enters Fortymile Wash. During a 100- or 500-year flood, both riparian areas would likely be damaged or destroyed by floodwaters regardless of the existence of the crossings.

Neither the quality nor the quantity of groundwater that normally recharges through Fortymile Wash would be substantially affected due to the crossings. Water infiltration could increase somewhat after large floods as standing water slowly enters the ground behind the crossings. The total volume of these water bodies would be a few acre-feet at most, and much of the water would gradually drain through culverts or evaporate before reaching the groundwater table at 274 meters (900 feet) below the surface.

The use of petroleum, oil, lubricants, and other hazardous materials during construction would be strictly controlled and spills would be promptly cleaned up and, if needed, the soil and alluvium would be remediated. The small amount of these materials that might enter the ground would not affect the groundwater, which is 274 meters (900 feet) below the surface.

The nearest population center is about 22 kilometers (14 miles) to the south, along U.S. 95 within the community of Amargosa Valley a few miles east of Fortymile Wash. If floodwaters from a 100- or 500-year flood reached this far downstream, there would be no measurable increase in flood velocity or sediment load attributable to the use of a route for heavy-haul trucks or construction of a rail line compared to natural conditions. Hence, disturbances to the floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, or Midway Valley Wash would have no adverse impacts on lives and property downstream. Moreover, impacts to these floodplains would be insignificant in both the short- and long-term compared to the erosion and deposition that occur naturally and erratically in these desert washes and floodplains.

During operation of the repository it would be extremely unlikely that a truck carrying spent nuclear fuel and high-level radioactive waste would fall into Busted Butte, Drill Hole, or Midway Valley washes or that a train would derail in Fortymile Wash. However, even if this occurred, the shipping casks, which are designed to prevent the release of radioactive materials during an accident, would remain intact. The casks would then be recovered and transported to the repository. No adverse impacts to surface water or groundwater quality from such accidents would occur.

Hazardous materials needed during construction and operation of the repository would be transported along the legal-weight access road. If these materials were released during an accident, they would be cleaned-up quickly and the affected soil and alluvium would be remediated. No adverse impacts to groundwater quality from such accidents would occur because cleanup could be completed before contaminants reached the groundwater [the groundwater table is 274 meters (900 feet) below the surface].

There are no positive or beneficial impacts to the floodplains of Busted Butte, Drill Hole, Midway Valley, or Fortymile washes that have been identified from the proposed action.

L.4.2 FLOODPLAIN/WETLANDS EFFECTS ELSEWHERE IN NEVADA

L.4.2.1 Effects along Rail Corridors

The candidate rail corridors, including their variations, would cross many small, and some large, washes. In general, the impacts caused by rail construction in any of these washes and their floodplains would be similar in magnitude to those described for Fortymile, Busted Butte, Drill Hole, and Midway Valley washes. Regardless of the corridor selected, standard mitigation practices would be used to minimize the impacts to floodplains. Most washes and their floodplains along the five candidate rail corridors are in remote areas. Impacts to these floodplains from rail construction and operation would be insignificant in both the short- and long-term compared to erosion and deposition that occurs naturally and erratically in these desert washes and floodplains.

Based on current information, springs and riparian areas that may have associated wetlands occur within three of the rail corridors (Caliente, Carlin, and Caliente-Chalk Mountain.) If the rail mode of spent nuclear fuel and high-level radioactive waste transport in Nevada is selected by DOE, wetlands delineations along the selected corridor would be conducted and the effects would be described in a more detailed floodplain/wetlands assessment for public review.

L.4.2.2 Effects at Intermodal Transfer Stations

Neither the Dry Lake intermodal transfer station nor the northern two sites being considered for the Sloan/Jean intermodal transfer station would have any impacts on floodplains because these station locations are not in a floodplain. The Caliente intermodal transfer station, however, is located in Meadow Valley Wash, separated by the Union Pacific Railroad and the southernmost of the Sloan/Jean sites is in the area of a wash or drainage channel between Interstate 15 on the west and the Union Pacific Railroad on the east. If one of these sites was selected, DOE would conduct a more detailed floodplain/wetlands assessment for public review to address the floodplain/wetlands effects at the Caliente or Sloan/Jean intermodal transfer station location. The more detailed floodplain/wetlands assessment would also include potential upgrades to existing roads for heavy-haul use.

L.5 Mitigation Measures

According to 10 CFR 1022.12(a) (3), agencies must address measures to mitigate the adverse impacts of actions in a floodplain or wetlands, including but not limited to minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically-sensitive areas. Whenever possible, DOE would avoid disturbing wetlands and floodplains and would minimize impacts to the extent practicable, if avoidance was not possible. This section discusses the floodplain mitigation measures that would be considered in the vicinity of Yucca Mountain and elsewhere in Nevada and, where necessary and feasible, implemented during construction and maintenance in the washes.

Adverse impacts to the affected floodplains would be small. Even during 100- and 500-year floods, it is unlikely that differences in the rate and distribution of erosion and sedimentation caused by the use of a route for heavy-haul trucks or construction of a branch rail line near Yucca Mountain would be measurably different compared to existing conditions. Similarly, upgrades to access roads and placement of excavated rock stockpiles within the site area would have little affect on erosion and sedimentation from flooding events. Nevertheless, DOE would follow their reclamation guidelines (DIRS 102188-YMP 1995, pp. 2-1 to 2-14) for site clearance, topsoil salvage, erosion and runoff control, recontouring, revegetation, siting of roads, construction practices, and site maintenance. Disturbance of surface areas and vegetation would be minimized, and natural contours would be maintained to the maximum extent feasible. Slopes would be stabilized to minimize erosion. Unnecessary off-road vehicle travel would be avoided. Storage of hazardous materials during construction would be outside the floodplains.

Before any potential construction could begin, DOE would require pre-construction surveys to make sure that the work would not impact important biological or archaeological resources. In addition, the site's reclamation potential would be determined during these surveys. In the event that construction could threaten important biological or archaeological resources, and modification or relocation of the roads and rail line is not reasonable, mitigation measures would be developed. Mitigation measures developed during the pre-construction surveys would be incorporated into the design of the work. These measures could include relocation of sensitive species, avoidance of archaeological sites, or data recovery if avoidance is not feasible.

If hazardous materials are spilled during construction of the crossings or during transport to the repository, the spill would be quickly cleaned-up and the soil and alluvium would be remediated. Hazardous materials would be stored away from all floodplains to decrease the probability of an inadvertent spill in these areas.

L.6 Alternatives

According to 1022.12(a)(3), DOE must consider alternatives to the proposed action. Alternative ways to access the Yucca Mountain site are considered in the following paragraphs, along with the No-Action Alternative.

L.6.1 ALTERNATIVES NEAR YUCCA MOUNTAIN

To operate a potential repository at Yucca Mountain, heavy-haul-capable and other roads and a branch rail line to the facility would be considered so the spent nuclear fuel and high-level radioactive waste could be unloaded and emplaced underground. It is unreasonable to consider a railroad or heavy-haul-capable and other roads that access the repository directly from the west over Yucca Mountain because of engineering constraints, environmental damage, and cost associated with construction in such rugged terrain. Because of these concerns, this alternative was eliminated from detailed consideration.

Access to Yucca Mountain from the east side requires that Fortymile Wash be crossed. Alternative sites for these crossings were considered, but the impacts at any alternative site would be virtually identical to each other.

L.6.2 ALTERNATIVE RAIL CORRIDORS AND ALTERNATIVE SITES FOR AN INTERMODAL TRANSFER STATION

Five candidate rail corridors were identified by DOE through a winnowing process that considered a host of environmental constraints (see Chapter 2, Section 2.3.3). Other possible rail corridors in Nevada were examined but rejected because of such things as land use, private land, and engineering constraints. Identification of the three intermodal transfer station locations was limited to reasonable sites next to an existing rail line in Nevada. Other sites were considered by DOE, but rejected because of ownership and environmental concerns.

L.6.3 NO-ACTION ALTERNATIVE

Selection of the No-Action Alternative would avoid impacts to floodplains and wetlands. If Yucca Mountain was selected as a site to construct a repository, transport of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would be required. In that case there would be no other practicable alternative to taking action in floodplains and wetlands because there would be no way to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site during repository operation without passing through some wetlands areas and floodplains.

L.7 Floodplain Statement of Findings

DOE prepared this Floodplain Statement of Findings based on the information in the above floodplain/ wetlands assessment. The assessment evaluates potential effects to the floodplains near Yucca Mountain (Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash) and to floodplains and wetlands elsewhere in Nevada from construction of a branch rail line or an intermodal transfer station and associated upgrades to existing highways for heavy-haul trucks. The assessment describes the proposed repository project and the existing environment near Yucca Mountain and elsewhere in Nevada along each of five candidate rail corridors and at three potential intermodal transfer station locations and five potential routes for heavy-haul trucks (see Figures L-1, L-2, and L-3 for location maps).

No repository surface facilities would be located in either the 100-year or the 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Wash, or Midway Wash. Access roads within the repository site would cross through upper portions of Drill Hole Wash and its tributaries. Stockpiles of rock

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excavated from the subsurface could also affect small drainage channels. Under the Proposed Action in this EIS, spent nuclear fuel and high-level radioactive waste would be shipped to the repository over approximately 24 years. Because there is no rail access to the Yucca Mountain site, DOE would need heavy-haul-capable and legal-weight roads or a potential rail line so that spent nuclear fuel and high-level radioactive waste could be delivered to Yucca Mountain. If the Yucca Mountain site was approved for development as a repository, there is no practicable alternative to locating roads and a potential rail line in a floodplain near Yucca Mountain.

Depending on the particular rail corridor or heavy-haul route selected, route construction and operations would affect floodplains in the vicinity of the Yucca Mountain site. These effects would occur from the installation of drainage culverts to cross some of the washes (e.g., Busted Butte and Drill Hole Washes), upgrading the existing road that crosses Fortymile Wash, or construction of a bridge for rail or heavy-haul traffic over Midway Valley Wash. Activities in the washes could also reduce the area through which floodwaters naturally flow. However, none of these impacts would be expected to increase the risk of future flood damage, or increase the impact of floods on human health and safety, or harm the natural and beneficial values of the floodplains because there are no human activities or facilities upstream or downstream that could be affected. There are no delineated wetlands at or near Yucca Mountain.

Similarly, elsewhere in Nevada, there would be no practicable alternative to taking action in floodplains and wetlands because there would be no means to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site without passing through some wetlands areas and floodplains.

In addition to the Proposed Action, the EIS analyzes a No-Action Alternative. Under the No-Action Alternative, no impacts to floodplains and wetlands would occur. DOE considered other alternative routes or access points to Yucca Mountain in addition to the five candidate rail corridors in Nevada and the three potential intermodal transfer station locations and five associated heavy-haul truck routes that are evaluated in the EIS. However, these other alternative routes or access points were eliminated from further detailed review on the basis of engineering constraints, environmental damage, and construction costs, and because they did not provide as direct a route to the repository as the candidate corridors and routes.

If Yucca Mountain was approved for development of a repository, DOE would choose either a rail corridor or an intermodal transfer station location and associated route for heavy-haul trucks to transport spent nuclear fuel and high-level radioactive waste to the repository. DOE would conduct a more detailed floodplains evaluation and wetlands delineation along the selected route. The effects and potential mitigation measures to be implemented for the selected route would be described in more detail in a floodplains and wetlands assessment to be issued for public review. DOE would minimize potential harm to or within a floodplain or wetland, such as by avoiding these resources in any selection of an alignment within a rail corridor.

Further, during any construction and operations at the Yucca Mountain site or elsewhere in Nevada along candidate rail corridors or at candidate sites for an intermodal transfer station, DOE would avoid disturbing wetlands, sensitive species, and floodplains wherever possible. If avoidance would not be practicable, standard mitigation practices would be used to minimize the potential impacts to floodplains and wetlands in the proposed project area and elsewhere in Nevada. Procedures would include preconstruction and biological surveys to identify and relocate sensitive species; avoiding archaeological sites (or data recovery where avoidance would not be feasible); modifying designs and implementing good engineering practices such as minimizing size of disturbance areas, topsoil salvage, preserving natural contours, surface erosion or runoff control; reclaiming and revegetating disturbed areas; and following established guidelines for hazardous materials storage and accidental spill response.

DOE's Proposed Action in floodplains would be conducted in accordance with all applicable requirements, including any applicable State or local floodplain protection standards.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Site Characterization Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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Appendix M

Supplemental Transportation Information

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APPENDIX M. SUPPLEMENTAL TRANSPORTATION INFORMATION

Radioactive materials are in common use in the United States for a wide range of purposes, including medical applications, precision instrumentation, and home products such as smoke detectors. Shipments of these materials occur throughout the country every day. A variety of regulations govern these shipments to ensure safety. Of the estimated 3 million annual radioactive material shipments, most involve low-level materials. Of the more than 2,700 shipments of commercial spent nuclear fuel completed over the past 30 years, none has resulted in an identified injury caused by the release of radioactive materials. While a repository would increase the total number of all radioactive materials shipments, spent nuclear fuel and high-level radioactive waste shipments would be a small fraction of the total. Furthermore, the number of shipments of radioactive materials is small in comparison to the 300 million annual shipments of hazardous materials.

The U.S. Department of Energy (DOE or the Department) developed this appendix to provide general background information on transportation-related topics not addressed in detail in Chapter 6 or Appendix J of this environmental impact statement (EIS). Although this information is not essential for analyzing potential impacts associated with transportation, DOE, in response to public comments on the Draft EIS, is including it to help the reader understand the regulatory framework and safety provisions associated with transporting spent nuclear fuel and high-level radioactive waste. This appendix describes the types of radioactive wastes commonly shipped by DOE and others and the relevant transportation requirements for each. In addition, it highlights the regulations developed by the U.S. Department of Transportation and the Nuclear Regulatory Commission to regulate virtually every aspect of the transportation of radioactive materials, including spent nuclear fuel and high-level radioactive waste. Further, it describes the transportation operations and requirements that would apply specifically to a Yucca Mountain Repository if it was recommended and approved. In that context, this appendix also discusses the safety and testing of transportation casks, emergency response in case of a transportation accident, physical protection of radioactive materials, and liability.

M.1 Spent Nuclear Fuel and Radioactive Wastes and General Transportation Requirements

Because the hazard levels of spent nuclear fuel, high-level radioactive waste, and other radioactive wastes vary, the transportation requirements for each also vary. This section describes spent nuclear fuel and other types of radioactive waste, and the general transportation requirements pertaining to each.

M.1.1 SPENT NUCLEAR FUEL

Spent nuclear fuel results from the production of electricity at nuclear powerplants or from the operation of other nuclear reactors, such as research reactors. Spent nuclear fuel is reactor fuel that has been withdrawn from a reactor following irradiation, the component elements of which have not been separated by reprocessing. It includes the following forms:

- Intact nondefective fuel assemblies
- Failed fuel assemblies in canisters
- Fuel assemblies in canisters
- Consolidated fuel rods in canisters
- Nonfuel assembly hardware inserted in pressurized-water reactor fuel assemblies
- Fuel channels attached to boiling-water reactor fuel assemblies
- Nonfuel assembly hardware and structural parts of assemblies resulting from consolidation in canisters

Any of the materials fitting this definition would be transported to a repository in shipping casks certified by the Nuclear Regulatory Commission under the regulations discussed in Section M.2.

M.1.2 HIGH-LEVEL RADIOACTIVE WASTE

High-level radioactive waste is a byproduct of the reprocessing of spent nuclear fuel. During reprocessing, spent nuclear fuel is separated into material to be reused, such as uranium and plutonium, and waste material for disposal. High-level waste includes liquid waste produced directly during reprocessing and solid material derived from such liquid waste that contains fission products in sufficient concentrations. Other highly radioactive wastes determined by the Nuclear Regulatory Commission to require permanent isolation can also be high-level waste. To date, there have been no such determinations. High-level waste would be transported in solid form to a repository in the same manner as spent nuclear fuel in accordance with the regulations discussed in Section M.2.

M.1.3 LOW-LEVEL RADIOACTIVE WASTE

Low-level radioactive waste is basically any radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, or byproduct materials, such as uranium mill tailings. It results from research, medical, and industrial processes that use radioactive materials. Commercial powerplant operations and defense-related activities, including weapons disassembly and cleanup of production sites, also produce low-level waste. In addition, repository operations, such as the decontamination of transportation casks and the decontamination and decommissioning of facilities after completion of operations, could generate low-level radioactive waste.

Low-level radioactive waste usually contains small amounts of short-lived radioactive material dispersed through large quantities of other material. It poses little transportation risk. Typically, such wastes consist of used protective clothing, rags, tools and equipment, used resins and residues, dirt, concrete, construction debris, and scrap metal. This waste is usually packaged in sturdy wooden or steel crates and steel drums for shipment. Because of its level of radioactivity, some types of low-level waste are transported in shielded Type B packages, which are certified by the Nuclear Regulatory Commission (see Section M.2.1). The Commission requires that all low-level waste be in solid form (free of liquids) before shipment to a disposal facility. The U.S. Department of Transportation requires carriers of low-level radioactive waste to use routes that minimize radiological risk [49 CFR 397.101(a)]. There are several sites across the United States for low-level radioactive waste disposal. Such waste would not be disposed of at Yucca Mountain.

Mixed waste contains both hazardous chemical components and radioactive components and is subject to the requirements of the Atomic Energy Act, as amended (42 U.S.C. 2011 *et seq.*) and the Resource Conservation and Recovery Act, as amended (42 U.S.C. 6901 *et seq.*). Most mixed waste is low-level; however, some transuranic waste is classified as mixed waste.

M.1.4 TRANSURANIC WASTE

Transuranic waste contains elements heavier than uranium, thus the name *trans-* (or beyond) *-uranic*. It results from both defense and nondefense production activities and includes contaminated protective clothing, tools, glassware, and equipment. Transuranic waste from defense production activities is disposed of at the Waste Isolation Pilot Plant in New Mexico. The transuranic waste category was established to separate long-lived, alpha-emitting radionuclides from the low-level radioactive waste stream. Thus, transuranic waste includes wastes contaminated with alpha-emitting transuranic radionuclides with half-lives greater than 20 years and concentrations greater than 100 nanocuries per gram. Waste containing less than 100 nanocuries per gram of transuranic contamination is classified as low-level waste. The gross radiation levels of transuranic waste are much less than those of high-level radioactive wastes, which emit significant amounts of beta and gamma radiation.

There are two types of transuranic waste, based on the amount of radioactivity. These wastes are typically shipped in 208-liter (55-gallon) drums or metal boxes transported in Type B packages. Almost all transuranic waste is *contact-handled*, meaning that it can be handled safely without shielding other than the drum or box. A small portion of transuranic waste is *remote-handled*, which must be transported in shielded casks.

DOE transports transuranic waste to the Waste Isolation Pilot Plant in New Mexico in accordance with U.S. Department of Transportation and Nuclear Regulatory Commission requirements. This transportation follows protocols agreed to in *Memorandum of Agreement for Regional Protocol for the Safe Transport of Transuranic Waste to the Waste Isolation Pilot Plant* (DIRS 155717-O'Leary 1995, all). Although not every shipment is classified as a Highway Route-Controlled Quantity of Radioactive Material, DOE has stated that, as a matter of policy, all shipments to the Waste Isolation Pilot Plant will follow U.S. Department of Transportation routing requirements for Highway Route-Controlled Quantities (see Section M.2.). A Highway Route-Controlled Quantity of Radioactive Material is a quantity in a single shipment that exceeds the amount of radioactivity specified in 49 CFR 173.425 and 10 CFR 71, Appendix A, Table A2. Highway and rail shipments of spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository, if approved, would meet the definition of Highway Route-Controlled Quantities of Radioactive Material.

M.2 Transportation Regulations

DOE shipments of spent nuclear fuel and high-level radioactive waste from reactors and DOE sites around the country to a repository at Yucca Mountain would comply with applicable Federal, Native American, state, and local government regulations. The U.S. Department of Transportation and the Nuclear Regulatory Commission share primary responsibility for regulating the safe transport of radioactive materials in the United States. These agencies have implemented regulations to govern the transportation of radioactive materials consistent with international transport safety standards.

The Hazardous Materials Transportation Act, as amended (49 U.S.C. 1801), directs the U.S. Department of Transportation to develop transportation safety standards for hazardous materials, including radioactive materials. Title 49 of the Code of Federal Regulations contains the standards and requirements for packaging, transporting, and handling radioactive materials for all modes of transportation.

The Nuclear Regulatory Commission regulates the transportation-related operations of its licensees, including commercial shippers of radioactive materials. It sets design and performance standards for packages that carry materials with higher levels of radioactivity (10 CFR). The Nuclear Waste Policy Act, as amended (NWPA; 42 U.S.C. 10101 *et seq.*), all shipments to Yucca Mountain would be made in Commission-certified packages and in accordance with Commission regulations on the advance notification of state and local governments (Section 180).

M.2.1 PACKAGING

Packages for radioactive materials that meet the standards required by U.S. Department of Transportation and Nuclear Regulatory Commission regulations (see Section M.4.1) are the primary means to protect people and the environment during the transportation of radioactive materials. The type of package required depends on the radiological hazard of the material being transported. Packages are selected based on activity, type, and form of the material to be shipped. There are four basic types of packages for transporting radioactive materials:

- *Excepted* packages are for materials with extremely low levels of radioactivity, such as instrumentation and smoke detectors.

- *Industrial* packages are for materials that present a limited hazard to the public, including contaminated equipment and radioactive waste solidified in materials such as concrete.

- *Type A* packages are for materials with higher concentrations of radioactivity, such as radiopharmaceuticals and low-level radioactive waste.

- *Type B* packages are for materials with radioactivity levels higher than those allowed in Type A packaging. Type B packages range from small containers of sealed radioactive sources to heavily shielded steel casks that sometimes weigh as much as 136 metric tons (150 tons). Examples of materials transported in Type B packages include spent nuclear fuel, high-level radioactive waste, and other materials with high concentrations of radioisotopes, such as cobalt sources.

Another option, the strong tight package, is available for some domestic shipments of radioactive materials. It is authorized only for domestic shipments of certain materials with low levels of radioactivity in a vehicle hired exclusively for their transport.

All spent nuclear fuel and high-level radioactive waste shipments to Yucca Mountain would be in the most rugged casks, Type B. The Nuclear Regulatory Commission regulates and certifies the design, manufacture, testing, and use of Type B packages under regulations contained in 10 CFR Part 71.

All radioactive materials must be properly packaged so that external radiation levels do not exceed regulatory limits. The packaging protects package handlers, transporters, and the public against receiving dose rates in excess of recognized safe limits. Regulations in 10 CFR 71.47 and 49 CFR 173.441 prescribe the external radiation standards for all packages. For shipments to the proposed repository, the radiation limits would be 10 millirem per hour at any point 2 meters (6.6 feet) from the outer edge of the truck trailer or railcar.

M.2.2 MARKING, LABELING, AND PLACARDING

U.S. Department of Transportation regulations require that shippers meet specific hazard communication requirements in marking and labeling packages that contain radioactive materials and other hazardous materials. Markings provide the proper shipping name, an emergency response identification number, the shipper’s name and address, and other important information. Labels are placed on opposite sides of a package to identify the contents and radioactivity level.

The required label is determined by the type of material shipped and measured radiation levels of the package contents. Shippers of radioactive materials use one of three labels: Radioactive White I, Yellow II, or Yellow III. The use of a particular label is based on the radiation level at the surface of the package and the transport index, which is a dimensionless number placed on the label of a package to indicate the degree of control to be exercised by the carrier during shipment. It is determined in accordance with 49 CFR 172.403.

- A White I label is for a package with a surface radiation level less than or equal to 0.5 millirem per hour and a transport index of 0.

- A Yellow II label is for a package with a surface radiation level greater than 0.5 millirem but less than or equal to 50 millirem per hour and a transport index of not more than 1.

- A Yellow III label is for packages that require the greatest degree of control by a carrier. These packages include ones in which:

  — The surface radiation level is greater than 50 millirem per hour but less than or equal to 200 millirem per hour, and the transport index is not greater than 10

  — The surface radiation level is between 200 and 1,000 millirem per hour or the transport index is greater than 10 (shipment must be by an exclusive use vehicle)

Almost all spent nuclear fuel and high-level radioactive waste shipments to Yucca Mountain would have Yellow III labels. Some shipments of irradiated reactor fuel components and empty shipping casks could have Yellow II labels.

In addition, vehicles transporting certain shipments of radioactive materials must have hazard communication placards displayed clearly on all four sides. Some shipments containing a high level of radioactivity, including spent nuclear fuel and high-level radioactive waste are, by regulation, *Highway Route-Controlled Quantities of Radioactive Materials* and must have the required "Radioactive" placard placed on a square white background with a black border.

The shipper and carrier are responsible for using the correct markings, labels, and placards. Compliance with the requirements is enforced by the U.S. Department of Transportation and, for licensees, can also be enforced by the Nuclear Regulatory Commission. Markings, labels, and placards identify the hazardous contents to emergency responders in the event of an accident.

M.2.3 SHIPPING PAPERS

The shipper prepares shipping papers and gives them to the carrier. These documents contain additional details about the cargo and include a signed certification that the material is properly classified and in proper condition for transport. For transport to the proposed repository at Yucca Mountain, commercial sites would present DOE with loaded shipping casks and a certification that the casks have been properly loaded, assembled, and inspected. For its licensees, which includes all commercial nuclear power reactors, the Nuclear Regulatory Commission can enforce U.S. Department of Transportation regulations regarding preparation and offering of shipments to carriers for transport.

Shipping papers also contain emergency information, including contacts and telephone numbers. Carriers must keep shipping papers readily available during transport for inspection by appropriate officials, such as state inspectors.

M.2.4 ROUTING

Motor carriers of Highway Route-Controlled Quantities of Radioactive Materials, such as spent nuclear fuel and high-level radioactive waste, are required to use *preferred routes* that reduce time in transit [49 CFR 397.101(b)]. A preferred route is an Interstate System highway (including beltways and bypasses) or an alternative route selected by a state routing authority in accordance with 49 CFR 397.103 using U.S. Department of Transportation *Guidelines for Selecting Preferred Highway Routes for Highway Route-Controlled Quantity Shipments of Radioactive Materials* (57 *FR* 44131; September 24, 1992) or an equivalent routing analysis that adequately considers overall risk to the public. Prior to the shipment of spent nuclear fuel, the shipper or carrier, as appropriate, must select routes and prepare a written plan for the Nuclear Regulatory Commission listing origin and destination of the shipment, scheduled route, all planned stops, estimated time of departure and arrival, and emergency telephone numbers. The Nuclear Regulatory Commission reviews and approves such routes.

Except for requirements contained in 10 CFR 73.37, there are no Federal regulations pertaining to rail routes for shipment of spent nuclear fuel or high-level radioactive waste. The shipper and railroad companies (carriers) determine rail routes based on best available route and track conditions, schedule efficiency, and cost effectiveness. The routes must be submitted in advance to the Nuclear Regulatory Commission for approval.

The U.S. Coast Guard has participated in establishing barge routes used for shipments from reactor sites. The names of the ports to be used must be submitted in advance to the Nuclear Regulatory Commission.

The EIS analysis used computer programs to select routes that are representative of routes that could be used to ship spent nuclear fuel and high-level radioactive waste to a Yucca Mountain repository. The computer programs applied the regulatory requirements and industry practices discussed in this appendix. If the repository was approved, actual shipment route selections would be submitted to the Nuclear Regulatory Commission for approval 1 or more years before shipments began. Section M.3.2.1.2 discusses route selection in greater detail.

M.2.5 PRIOR NOTIFICATION

Nuclear Regulatory Commission regulations (10 CFR Part 73) provide for written notice to governors or their designees in advance of irradiated reactor fuel through their states. Federal regulations allow states to release certain advance information to local officials on a need-to-know basis. As required by Section 180 of the NWPA, all shipments to a repository would comply with Commission regulations on advanced notification to state and local governments.

The Nuclear Regulatory Commission is in the process of changing the requirements so that Native American governments would be notified under the Commission's notification rule (64 *FR* 71331, December 21, 1999). Notification of shipments to a repository would be in accordance with Commission regulations in effect at that time.

M.2.6 TRAINING

U.S. Department of Transportation regulations (49 CFR Part 391) require anyone involved in the preparation or transport of radioactive materials, including loading and unloading, packaging, documentation, or general transport safety, to have proper training. In accordance with 49 CFR 172, Subpart H, operators of vehicles transporting Highway Route-Controlled Quantities of Radioactive Materials receive special training that covers the properties and hazards of the radioactive materials being transported, regulations associated with hazardous material transport, and applicable emergency procedures. Operators must be recertified every 2 years.

M.2.7 OTHER REQUIREMENTS

Organizations representing different transport modes often establish mode-specific standards. For example, all North American shipments by rail that change carriers must meet Association of American Railroads interchange rules. Equipment in interchanges must meet Association of American Railroads *Field Manual of the A.A.R. Interchange Rules* (DIRS 102592-AAR 1998, all) requirements.

The Commercial Vehicle Safety Alliance has developed inspection procedures and out-of-service criteria for commercial highway vehicles transporting transuranics, and Highway Route-Controlled Quantities of

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Radioactive Materials (see Section M.3.2.2.2). All highway shipments to a repository would be inspected under these procedures and would not leave the site until the vehicle was determined to be defect-free.

M.3 Transportation Plans and Requirements Specific to the Proposed Repository

This section describes current plans for implementing Section 137 of the NWPA, which requires DOE to utilize private industry to the fullest extent possible in each aspect of the transportation of spent nuclear fuel to a repository. These plans do not apply to shipment of naval spent nuclear fuel. The U.S. Department of the Navy would be responsible for transporting its spent nuclear fuel to the repository. Shipments of naval spent nuclear fuel would comply with the applicable regulations of the U.S. Department of Transportation, states, local governments, and Native American tribes. Shipping casks used for naval spent nuclear fuel would be certified by the U.S. Nuclear Regulatory Commission.

M.3.1 ACQUISITION OF CONTRACTOR SERVICES FOR WASTE ACCEPTANCE AND TRANSPORTATION

As required by Section 137 of the NWPA, DOE would utilize private industry to the fullest extent possible in each aspect of the transportation of spent nuclear fuel to the proposed repository. In September 1998, DOE published a draft Request for Proposal, *Acquisition of Waste Acceptance and Transportation Services for the Office of Civilian Radioactive Waste Management* (DIRS 153487-DOE 1998, all). According to this draft document, DOE would purchase services and equipment from *Regional Servicing Contractors* who would perform waste acceptance and transportation operations. If the site was approved, DOE has identified key areas of the draft Request that would require further refinement before a final solicitation, including the method of contract financing and payment. There are also specific areas related to the physical transfer of spent nuclear fuel that would be addressed before a final request. DOE is reviewing these areas and, accordingly, revising its strategy to acquire and deploy the transportation infrastructure to begin receiving shipments at Yucca Mountain in 2010. DOE would review and update the request and reissue it for further comment before issuing a final request.

As stated in the draft Request, DOE could use competitive fixed-price type or fixed-rate contracting. In addition, during several decades of operations, DOE would issue several Requests for Proposal with multiple awards, dividing the country into four regions, perhaps based on the four Nuclear Regulatory Commission regions, with one contractor to service each region. A *Regional Servicing Contractor* would receive no more than two regional servicing contracts. Regional Servicing Contractors would:

- Comply with applicable Federal (Nuclear Regulatory Commission, and U.S. Department of Transportation), state, local, and Native American regulations
- Work with utilities (generators) to determine the best way to service a site and integrate site planning into a regional servicing plan
- Provide all hardware, including transportation casks, canisters, and ancillary lifting equipment
- In conjunction with DOE, interact with state, local, and Native American governments as appropriate
- Provide all acceptance and transportation services necessary to move spent nuclear fuel from the generator sites to the proposed repository

DOE would retain responsibility for policy decisions, state and Native American relations, final route selection, and implementation of Section 180(c) of the NWPA. These activities would not be delegated to the Regional Servicing Contractor.

Under current draft plans, contracts would have three phases:

- Phase A: Development of site-specific and regional servicing plans and fixed-price bids, followed by authorization of one Regional Servicing Contractor per region to continue work into Phase B
- Phase B: Mobilization of transportation services, finalization of transportation routes and training, acquisition of transportation equipment (through lease or purchase)
- Phase C: Actual performance of acceptance activities and movement of spent nuclear fuel and high-level radioactive waste once a repository became operational

The plan for the acceptance of spent nuclear fuel would be consistent with DOE obligations under the Standard Contract (10 CFR Part 961). Acceptance schedules would be based on receiving spent nuclear fuel from generators consistent with allocations based on the acceptance priority ranking specified in the Standard Contract. In developing site-specific servicing plans, contractors could propose alternative schedules to enhance cask utilization and improve operational efficiency. The alternative schedules would require the consent and approval of the utility involved.

M.3.2 OPERATIONAL PRACTICES

Each Regional Servicing Contractor would be required to prepare a transportation plan that described the Contractor's operational strategy and delineated the steps it would implement to ensure compliance with all regulatory and other DOE requirements. This would include identification of proposed routes and associated routing considerations, coordination and communication with all participating organizations and agencies, and interactions with appropriate Federal, Native American, and state organizations. DOE would provide the draft transportation plan from each Regional Servicing Contractor selected for Phase B work to the states and tribes through whose jurisdictions spent nuclear fuel would be shipped for review and comment.

The draft Request for Proposal sets forth DOE requirements for the overall approach for transportation operations (DIRS 153487-DOE 1998, Section C, Appendix 8). These requirements are either based on or in addition to other Federal, state, or Native American regulatory requirements. Many of these practices are followed for shipments of transuranic waste to the Waste Isolation Pilot Plant in New Mexico. This section summarizes the requirements. In addition, DOE is developing transportation practices it can apply to all Department activities. The requirements or practices discussed in this section could be modified as appropriate to reflect these developing practices. In addition, DOE would implement requirements contained in applicable revisions to Federal, state, Native American, and local laws and regulations that applied to shipment of spent nuclear fuel and high-level radioactive waste.

These practices pertain primarily to activities associated with the Regional Servicing Contractor and DOE. In addition, the utility or Federal facility from which spent nuclear fuel or high-level radioactive waste would be shipped would play an important role in the transportation process. It would provide trained operators to load shipping casks and prepare them for shipment. This would include initial cask (or canister) receipt at the facility, completion of receipt inspections, and preparation activities before loading. The cask would be loaded according to the specifications listed on the Certificate of Compliance issued by the Nuclear Regulatory Commission for the particular cask. After the cask was loaded and placed on the transporter, preshipment inspections and tests would be conducted. These would include such things as leak tests, checking to ensure all lid bolts were fastened properly, and checking to see that impact limiters were attached properly. The cask would be checked for surface contamination and to ensure that radiation levels were within regulatory limits. The shipper, DOE, would be provided with the information necessary to complete the shipping papers. In the case of a highway shipment, the vehicle, load, and driver would be inspected according to procedures described in the Commercial Vehicle Safety Alliance North American Uniform Standard Out-of-Service Criteria (DIRS 156422-CVSA 2001, all) (see 49 CFR Part 397).

M.3.2.1 Planning and Mobilization

The requirements described in this section are associated primarily with Phase A and Phase B planning and mobilization activities. These requirements would be used to establish the baseline operational organization and practices to be used during early mode and route identification, fleet planning and acquisition, carrier interactions, and operations.

M.3.2.1.1 *Transportation Mode Selection*

The Regional Servicing Contractor would receive a current Delivery Commitment Schedule (described in 10 CFR Part 961) and other supporting data for each site to be serviced. These documents would provide information to support site-specific recommendations for the transportation mode, based on generator facility capabilities. This information could include a specific mode reflecting a generator’s preference. In this case, the Regional Servicing Contractor would have to provide transportation systems compatible with this mode designation unless other infrastructure constraints made the generator’s designation impractical. Suitability of the near-site infrastructure would be based on an evaluation of existing roads, railroads, bridges, etc., without modifications or upgrades. As stated in the draft Request for Proposal, DOE prefers to use rail transport wherever practical (DIRS 153487-DOE 1998, p. C-14). In addition, the Contractor would be required to use dedicated trains for shipments whenever such trains were determined to provide improvements in safety and enhance the efficiency of transport operations and logistics.

M.3.2.1.2 *Route Selection*

All routes used to transport radioactive waste would comply with applicable regulations of the U.S. Department of Transportation and the Nuclear Regulatory Commission. Under current planning, the Regional Servicing Contractor would have to meet the additional requirements described below when identifying proposed transportation routes (DIRS 153487-DOE 1998, all). The Contractor would consult with the other Regional Servicing Contractors as appropriate to ensure continuity and consistency of routes. All recommendations for pickup routes would be consistent with the suitability of the supporting infrastructure based on evaluations using existing roads, docks, bridges, channels, etc., without modification or upgrade, for highway routes, and would comply with the requirements in 49 CFR 397.101. After identifying a specific route, the Contractor would submit the route plan to DOE for approval. DOE would interact with states and Native American governments concerning these selections. With DOE approval, the Contractor would then submit the route plans to the Nuclear Regulatory Commission in accordance with 10 CFR 73.37(a)(7). (Actual route selection and submission to the Commission would occur 1 or more years before a route’s use for shipment. Though the EIS applied the selection methodology described in this appendix, actual routes could differ from those used in the analyses.)

Almost all DOE commercial spent nuclear fuel highway shipments under a Regional Servicing Contract would be Highway Route-Controlled Quantities of Radioactive Material. Therefore, U.S. Department of Transportation routing rules (49 CFR 397 Subpart D) would apply. As specified in 49 CFR 397.101(b)(1), the Regional Servicing Contractor would have to use preferred routes that reduced time in transit.

The Regional Servicing Contractor would identify rail transportation routes in conjunction with the appropriate rail carriers. Because railroad companies determine the routing of shipments, the Contractor would rely on the rail carrier to provide primary and secondary route recommendations consistent with safe railroad operating practices. Guidelines would include consideration of track classification to ensure use of the highest rated track to the greatest extent possible, and maximum use of *key routes* as described in *Recommended Railroad Operating Practices for Transportation of Hazardous Materials* (DIRS 155658-AAR 2000, all), which requires specific inspection, maintenance, and operating procedures for key routes.

The Regional Servicing Contractor would identify barge and heavy-haul truck transportation routes in conjunction with the respective carriers and, as appropriate, discussions with state, local, U.S. Coast Guard, and U.S. Army Corps of Engineers representatives and Port Captains. Discussions about barge shipments would include development of a marine transportation plan, specific barge/cask interface requirements, availability of tug services, and identification of preshipment inspections and marine surveys. The heavy-haul truck route identification process would be in conjunction with, and in compliance with, the requirements of the routing agency of the state(s) in which shipments would occur and the applicable U.S. Department of Transportation requirements.

The Regional Servicing Contractor would be responsible for conducting studies or analyses necessary to support route recommendations, including identification of intermodal transfer locations, if needed. The Contractor would also be responsible for obtaining the necessary permits or authorizations, including payment of fees, rents, or leases associated with barge or heavy-haul truck operations.

M.3.2.1.3 *Safe Parking Areas*

Highway shipments of spent nuclear fuel or high-level radioactive waste could be delayed en route due to mechanical problems, weather or road conditions, or other unanticipated problems. In anticipation of such events, the Regional Servicing Contractor would identify safe parking areas along each highway route as part of the route determination process. The key factors in selecting a safe parking area would be (1) the desirability of a particular type of parking area and (2) the ability of the driver and crew to reach that parking area under different types of unanticipated delays or emergencies. The prioritized criteria for the identification and selection of safe parking areas include the following:

1. DOE facilities (as identified by DOE)

2. Specific places designated by DOE or the state; for example:

   - U.S. Department of Defense facilities
   - Truck stops
   - Rail sidings (with railroad concurrence)
   - Ports of entry
   - State highway service facilities
   - National Guard facilities

3. If none of the parking options under the first two choices could be reached safely, criteria for the avoidance of particular types of areas would be applied to select a suitable safe parking area. Although it might not be possible to locate a parking site that met all of the following criteria, the plan would be to avoid the following types of potential parking locations:

   - Highly populated areas
   - Hospitals and schools
   - Residential areas

- Areas with numerous pedestrians
- Heavily industrialized areas
- Areas with difficult access
- Crowded parking areas (such as shopping malls)
- Highway shoulders

Safe parking areas should also:

- Provide adequate separation from other vehicles carrying hazardous materials
- Facilitate required security (such as maintaining observation of the vehicle)
- Provide adequate driver and crew services

M.3.2.1.4 *Adverse Weather, Road, and Rail Conditions*

The Regional Servicing Contractor would obtain route weather forecast information as part of the preshipment planning and notification and shipment dispatching process. At the time of departure, current weather conditions, the weather forecast, and current travel conditions would have to be acceptable for safe vehicle operation. If these conditions were not acceptable, the shipment would be delayed until travel conditions became acceptable. The driver and crew would concur with the decision to dispatch the shipment(s). Shipments would not travel when severe weather conditions developed along routes or adverse road conditions made travel hazardous. Driver and crew communications with the control center would provide advance warning of potential adverse conditions along the route. If the shipment encountered unanticipated severe weather or adverse road conditions, the driver and crew would contact the control center to coordinate routing to a safe parking or stopping area if it became necessary to delay the shipment until conditions improved.

DOE would provide the Regional Servicing Contractor with notification of road or highway construction that could temporarily affect the planned route. DOE would obtain road and highway conditions and information on anticipated construction through consultation with the states along the planned route. Long-range highway construction planning information provided by state highway departments would be given to the Contractor. This information would aid in confirming final shipping schedules and determining if short-term alternative route planning and additional approvals by the states or the Nuclear Regulatory Commission would be required before initiating the shipments.

Rail carriers use train control and monitoring systems to identify the location of their trains within the rail system and to make informed decisions based on this information to avoid or minimize potential weather-related or track-condition risks. Under 49 CFR 174.20, the carrier can impose local restrictions on transportation when local conditions make travel hazardous. Adverse operating conditions can be reported to the DOE shipper through several means (for example, communications with the carrier or information provided by state, Native American, or local authorities).

M.3.2.1.5 *Tracking and Communication*

Shipment tracking and preshipment and communications en route would be key responsibilities of the Regional Servicing Contractor. A system that provided the necessary tracking and communications with DOE, affected governments, other Regional Servicing Contractors, and the repository would be in place at all times.

The Regional Servicing Contractor would provide continuous real-time position tracking for all shipments using the TRANSCOM satellite tracking system or an equivalent system approved by DOE. The system would provide DOE and the Contractor with a continuous, centralized monitoring and communications capability. The Contractor would be responsible for acquisition, installation, maintenance, and security of the tracking system equipment.

The Regional Servicing Contractor would develop detailed procedures to be followed in the event that the tracking system was temporarily not available. The procedures would be based on a telephone call-in system that provided for the driver or other crew member reporting the shipment location to DOE on a regular basis and before crossing state and tribal borders.

In addition to the satellite tracking system, the Regional Servicing Contractor would furnish and equip all tractors and rail escort cars with communications equipment.

M.3.2.1.6 *Carrier Management Plan*

The Regional Servicing Contractor would be responsible for selecting and using transportation carriers that complied with all applicable regulatory and DOE operational transportation requirements. The Contractor would require all carrier subcontractors to provide a carrier management plan that addressed the following areas:

- Management organization, including subcontractor management
- Driver and crew screening and hiring
- Driver and crew operations and safety training and refresher training
- Maintenance and inspection of personnel qualifications
- Maintenance program, including procedures and inspections
- Pretrip and posttrip inspection requirements
- Maintenance en route or breakdown repair or equipment replacement
- Emergency or incident response training and refresher training
- Accident or incident reporting system
- Policy for imposition of specific driver and crew penalties
- Substance abuse policy, including screening tests
- Security plan
- Quality assurance plan
- Safety program
- Records management system

M.3.2.1.7 *Carrier Personnel Qualifications*

Carriers would develop and maintain a qualification and training program that meets U.S. Department of Transportation and Nuclear Regulatory Commission requirements for drivers, engineers, crew, and security personnel. For truck drivers, qualifications include being at least 21, meeting physical standards, having a commercial driver's license, and successfully completing a road driving test in the shipment vehicle. In addition, drivers must have training on the properties and hazards of the material being transported, as well as the procedures to follow in the event of an emergency. Locomotive engineers must meet the Locomotive Engineer Certification requirements of 49 CFR Part 240, which include completing an approved training program. In addition to these requirements, driver and crew training would cover the following:

- Operation of the specific package tie-down systems

- Cask recovery procedures

- Use of radiation detection instruments

- Use of a satellite-based tracking system and other communications equipment
- Adverse weather and safe parking procedures
- First responder awareness training
- Radiation worker B (or equivalent) training
- Enhanced inspection standards as specified in the Commercial Vehicle Safety Alliance North American Uniform Standard Out-of-Service Criteria (DIRS 156422-CVSA 2001, Paragraph 5.0)
- The "Physical Protection of Irradiated Fuel in Transit, Training Program" (10 CFR 73, Appendix D), which includes security requirements

M.3.2.2 Shipment Operations

M.3.2.2.1 *Notice of Shipments*

Advance notice of DOE shipments, ongoing status of shipments, and other pertinent shipment information would be necessary to meet regulatory requirements [10 CFR Part 71.97, 10 CFR 73.37 (f), and 10 CFR 73.72]. This information would be used to support coordination of repository receipt operations, support emergency response capabilities, identify weather or road conditions that could affect shipments, identify safe parking locations, schedule needed inspections, and coordinate public information programs.

The Regional Servicing Contractor would provide projected shipping schedules to DOE. DOE would provide schedule information to the states and tribes based on specific approved routes approximately 6 months before the initiation of planned shipments.

M.3.2.2.2 *Inspections*

Inspections of highway shipments would be conducted at the points of origin and destination using the enhanced inspection standards of the Commercial Vehicle Safety Alliance (DIRS 156422-CVSA 2001, all). DOE selected the Commercial Vehicle Safety Alliance, an international organization of state and province officials responsible for the administration and enforcement of motor carrier safety laws, to develop an inspection and enforcement program specific to spent nuclear fuel, high-level radioactive waste, transuranics and other Highway Route-Controlled Quantities of Radioactive Material. The procedures developed under this program provide uniform standards for radiation surveys, inspection of drivers, shipping papers, vehicles, and casks. The procedures set higher standards for these shipments than are contained in the North American Inspection Standards, which are used to inspect all other types of shipments. The procedures are used to inspect a shipment at point of origin. A vehicle receives a special inspection decal, good only for that shipment, if it is defect-free according to the enhanced standards. The Commercial Vehicle Safety Alliance has trained state inspection personnel on the enhanced procedures, which are currently being applied to DOE shipments (DIRS 156703-FRA 1998, all) of transuranics and other Highway Route-Controlled Quantities of Radioactive Material.

Rail shipments would be inspected in accordance with 49 CFR 174.92 and the Federal Railroad Administration's High-Level Nuclear Waste Rail Transportation Inspection Policy. The policy states (DIRS 156703-FRA 1998, Appendix A):

> *Past rail shipping campaigns of high-level nuclear waste have shown that the nature of the potential hazards associated with radioactive materials elicits a relatively high degree of public awareness and*

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concern in regard to transportation of the material. As a result, the Federal Railroad Administration developed and instituted an inspection policy for rail movements of this type of hazardous material. This policy sets inspection frequency criteria above and beyond that which may normally be necessary and is implemented for all known high-level nuclear waste shipments by rail.

In addition to pre- and postshipment inspections of the transport package and crew safety inspections en route of the transport vehicles, DOE anticipates that various states and tribes could require additional vehicle inspections when shipments entered their respective jurisdictions. For barge shipments, inspections and surveys would be in accordance with U.S. Coast Guard regulations (46 CFR Parts 90 to 105). Inspections en route would be scheduled using the satellite system and other position-reporting capabilities to notify appropriate jurisdictions of the approach of a shipment so state or tribal inspection officials could be available at designated points to perform the inspection with minimal disruption to operating schedules. Inspections for rail shipments would be coordinated with normal crew change locations wherever possible to minimize additional stops.

M.3.2.2.3 *Procedures for Delays En Route*

The Regional Servicing Contractor would be responsible for providing or having carriers provide drivers and crews with specific written procedures that clearly defined detailed actions the driver and crew would take in the event of various delays en route. These include unanticipated route conditions due to civil strife or other disruptions, traffic delays due to traffic accidents not directly involving the cask shipments, emergency road or rail construction, or delays caused by sudden or unanticipated weather conditions. Procedures would address notifications, maintaining security, selecting alternative routes or route detours, or moving to the nearest safe parking area.

M.3.2.2.4 *Procedures for Off-Normal Operations (Unrelated to Accidents, Incidents, or Emergencies)*

The Regional Servicing Contractor would be responsible for providing or having carriers provide drivers and crews with specific written procedures that clearly defined detailed actions that the driver and crew would take during off-normal events. These include, but are not limited to, mechanical breakdown, fuel problems, tracking system failure, and illness, injury, or other incapacity of the driver or a member of the crew. Procedures would address notifications, deploying appropriate hazard warnings, maintaining security, obtaining medical assistance, arranging for crew replacement or for maintenance, repair, or replacement of equipment, or recovery, as appropriate.

M.3.2.2.5 *Emergency or Incident Response*

The Regional Servicing Contractor would be responsible for providing or having carriers provide drivers and crews with specific written procedures that clearly defined detailed actions they would take in the event of an emergency or incident involving property damage, injury, or the release or potential release of radioactive materials. Procedures would comply with U.S. Department of Transportation guidelines for emergency response contained in the *2000 Emergency Response Guidebook* (DIRS 155776-DOT 2000, all) and would address the following:

- Emergency assistance to injured crew or others involved
- Identification and assessment of the situation
- Notification and communication requirements
- Securing the site and controlling access
- Technical help to first responders

M.3.2.3 Postshipment Activities

Postshipment activities would include inspections of each loaded transport casks and, after completion of unloading operations, maintenance or reconfiguration and preparation of the cask and other supporting transportation system equipment for temporary parking at the proposed repository or redeployment for more shipments.

M.3.2.3.1 *Postshipment Radiological Surveys*

Receiving facility operators would survey each cask and transporter on arrival and receipt at the proposed repository and, before initiating unloading operations, would determine if any contamination beyond the limits specified in 49 CFR 173.443 occurred during transit. In addition, the cask, its tie-downs, and associated transportation system hardware would be inspected visually to ensure that no physical damage occurred during transit.

DOE, as the shipper, would be responsible for reporting any contamination or damage to the Nuclear Regulatory Commission in accordance with 10 CFR 71.95. The Department would also be responsible for notifying the utility at whose facility the shipment originated and, with the utility, for initiating corrective actions. In addition to reports required for the Nuclear Regulatory Commission, the DOE Office responsible for repository operations would provide a report to DOE Headquarters describing the incident, including probable cause, and the corrective actions taken to prevent recurrence.

M.3.2.3.2 *Shipment of Empty Transportation Casks*

Except before their first use, shipments of all empty transportation casks would comply with the requirements of the Nuclear Regulatory Commission certificate of compliance or 49 CFR 173.427, whichever was applicable. Escort and security requirements, advance shipment notifications, continuous position tracking, and inspections en route would not apply to the shipment of empty transportation casks.

M.4 Cask Safety and Testing

M.4.1 TEST REQUIREMENTS FOR CASKS

The purpose of the Nuclear Regulatory Commission regulations applicable to the transportation of spent nuclear fuel and high-level radioactive waste materials to the proposed repository is to protect the public health and safety for normal and accident conditions of transport and to safeguard and secure shipments of these materials. Regulations in 10 CFR Part 71 require that casks for shipping spent nuclear fuel must be able to meet specified radiological performance criteria for normal transport and following a sequential series of tests that represent severe accident conditions. Meeting these requirements is an integral part of the safety assurance process associated with transportation casks. The ability of a design to withstand the test conditions can be demonstrated by comparing designs to similar casks, engineering analyses (such as computer-simulated tests), or by scale-model or full-scale testing. These tests include a 9-meter (30-foot) drop onto an unyielding flat surface, a 1-meter (40-inch) drop onto a vertical steel bar, exposure of the entire package to fire for 30 minutes, and immersion in 1 meter (3 feet) of water. In addition, an undamaged cask must be able to survive submersion in the equivalent pressure of 15 meters (50 feet) and 200 meters (650 feet) of water. Studies conducted by the Nuclear Regulatory Commission show that these test conditions simulate almost all observed or anticipated accidents (DIRS 101828-Fischer et al. 1987, all; DIRS 152476-Sprung et al. 2000, all; see Section M.4.2). For most accidents more severe than those represented by the test conditions, the Nuclear Regulatory Commission studies show that the radiological criteria for containment, shielding, and subcriticality are still satisfied. The studies also show that for the few severe accidents in which these criteria could be exceeded, only containment and shielding would be affected, and the regulatory criteria could be exceeded only slightly. The following paragraphs discuss each of these tests.

M.4.1.1 Nine-Meter Drop onto an Unyielding Surface

The first test in the accident sequence simulates impact. The test is specified as a 9-meter (30-foot) free fall onto an unyielding surface with the cask striking the target in the most damaging orientation. The free fall results in a final velocity of 48 kilometers (30 miles) per hour. Although this velocity is less than the expected speed of interstate highway traffic, the test is severe because the target surface is unyielding. This results in all the energy of the drop being absorbed by the cask. There is no such thing in nature as an unyielding surface. Striking an unyielding surface at 48 kilometers per hour, when all the impact energy is absorbed by the cask, is approximately equivalent to a 97-kilometer (60 mile)-per-hour impact with a “medium” hardness surface, such as shale or other relatively soft rock, and a 150-kilometer (90 mile)-per-hour impact with a “soft” surface, such as tillable soil.

M.4.1.2 One-Meter Drop onto a Steel Bar

The second test in the sequence simulates a cask hitting a rod or bar-like object that could be present in an accident. The test is specified as a 1-meter (40-inch) drop onto a 15-centimeter (6-inch)-diameter rod sitting on the unyielding surface. The cask must be in the orientation in which maximum damage would be likely. In addition, the bar must be long enough to cause maximum damage to the cask. The test frequently evaluates several impacts in which different parts of a cask strike the bar either by simulation or physical testing. This is to demonstrate that all parts of the cask would pass the test.

M.4.1.3 Fire Test

The third test in the sequence simulates a fire occurring after the two impacts described above. The test is specified as a 30-minute engulfing hydrocarbon fire with an average flame temperature of 800°C (1,472°F). The test requires the cask to be fully engulfed in the flame for the full 30 minutes. Following an actual severe accident a cask would probably be lying on the ground in a position such that it would not be fully engulfed.

M.4.1.4 Water Immersion Tests

The fourth and final test of the sequence is a shallow immersion test. The test cask (after being subjected to the two drops and the fire) must next be immersed in 1 meter (3 feet) of water. The purpose of this test is to ensure that water cannot leak into the cask.

An undamaged version of the cask must also be able to survive immersion in the equivalent of 15 meters (50 feet) of water [a pressure of about 1,500 grams per square centimeter (22 pounds per square inch)] to test for leakage. Furthermore, shipping casks designed to hold more than 1 million curies of radioactivity must be able to survive water pressure of about 20,000 grams per square centimeter (290 pounds per square inch) for 1 hour without collapse, buckling, or leaking. That pressure is equivalent to a depth of about 200 meters (650 feet). The purpose of this standard is to ensure that casks accidentally sunk on the outer continental shelf could be retrieved with their contents intact.

M.4.1.5 Acceptance Criteria

To be judged successful in meeting these tests [except the 200-meter (650-foot) submersion], a cask must not release more than limited amounts of radioactive material in 1 week. These release limits are set for each radionuclide based on dispersivity and toxicity. In addition, it must not emit radiation at a dose rate of greater than 1 rem per hour at a distance of 1 meter (3 feet) from the cask surface. Finally, the spent nuclear fuel or high-level radioactive waste in the cask must not be capable of undergoing a nuclear chain reaction, or criticality, as a result of the test conditions. A recent study by Sandia National Laboratories for the Nuclear Regulatory Commission determined that less than 1 in 10,000 transportation accidents involving casks that satisfy the performance requirements of the Commission regulations would be severe enough to cause a release from a spent nuclear fuel cask (DIRS 152476-Sprung et al. 2000, pp. 7-73 to 7-76).

M.4.1.6 Tests Using Models

The ability of a cask to survive these tests can be demonstrated in several ways. First, an actual, full-size model of the cask can be subjected to all the tests in the sequence. As an alternative, the tests can be applied to small models of the casks (typically half- or quarter-scale). Finally, cask designs can be compared to previous licensed designs or analyzed with computer models. The Nuclear Regulatory Commission decides what level of physical testing or analysis is necessary for each cask design. Because the Commission generally accepts the results of scale-model testing, expensive full-scale testing of entire spent fuel casks is rarely conducted, although such tests are sometimes required for specific cask components. For example, the Commission could require quarter-scale drop tests for a particular cask design but full-scale tests of the cask's impact limiters (cushioning material typically attached to each end). Computer analysis could be sufficient for meeting the fire test and for criticality control.

M.4.2 STUDIES OF TRANSPORTATION ACCIDENT RISK

This section presents information from the recent report to the Nuclear Regulatory Commission from the Commission staff, "Transportation Risk Studies" (DIRS 155562-NRC 2000, all).

Federally funded studies of nuclear waste transportation accident risks have concluded that current regulations provide an adequate margin of safety. For example, the Nuclear Regulatory Commission first evaluated impacts on public health and safety from transportation activities in the *Final Environmental Impact Statement on the Transportation of Radioactive Materials by Air and Other Modes* (DIRS 101892-NRC 1977, all). This document examined impacts from transportation by land, air, and sea transport modes under incident-free and accident conditions.

Considering the information developed and received, and the safety record associated with the transportation of radioactive material, the Commission determined that the regulations then in place were adequate to protect the public against unreasonable risk from the transport of radioactive materials, and that no immediate changes in the regulations were needed to improve safety (46 *FR* 21619; April 13, 1981). The U.S. Department of Transportation also relied on DIRS 101892-NRC (1977, all) to assess the impact of radioactive material transportation under its Hazardous Materials regulations (49 CFR Subchapter C, Parts 171 to 180).

In the mid-1980s, several shipment campaigns were initiated to return spent nuclear fuel from the West Valley Demonstration Project in western New York to the originating utilities. These campaigns drew considerable public interest, and questions focused on the difficulty in comparing the Nuclear Regulatory Commission's spent fuel cask accident standards with actual accident conditions. These standards are expressed as a series of hypothetical tests and acceptance criteria described in 10 CFR 71.73. The Commission addressed the level of safety provided by its regulations under accident conditions in a study, which is frequently referred to as the *Modal Study* conducted for the Commission by Lawrence Livermore National Laboratory [*Shipping Container Response to Severe Highway and Railway Accident Conditions* (DIRS 101828-Fischer et al. 1987, all)].

To elaborate on the DIRS 101892-NRC (1977, all) spent nuclear fuel shipment accident risk estimate, the Modal Study included an assessment of the probabilities and forces associated with severe transportation accidents. In addition, the Modal Study examined transport cask responses to accidents by using finite element modeling of generic cask responses to accident forces. The results indicated that spent nuclear fuel shipment risks were about one-third those estimated in DIRS 101892-NRC (1977, p. 5-51 to 5-53). From the Modal Study, the Nuclear Regulatory Commission concluded that the study clearly bounded spent nuclear fuel shipment risks, which supported the Commission's previous decision that there was no need to change transportation regulations to improve safety.

Another recent study by Sandia National Laboratories for the Nuclear Regulatory Commission, the *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, all) examined whether the original Modal Study risk estimates bounded those for the anticipated shipment campaigns. Like the Modal Study, this study calculated the risks for spent nuclear fuel shipments under incident-free and accident conditions but, unlike that study, considered such factors as the design, enrichment, burn-up, and cooling time of fuel currently anticipated to be shipped; the capacity and designs of newer casks; and current population densities along road and rail routes. The results of this study continue to show that accident risk estimates are much less than those estimated in DIRS 101892-NRC (1977, all).

An ongoing transportation accident risk study, the *Package Performance Study* focuses on spent nuclear fuel cask responses to severe transportation accidents (see 65 *FR* 45629; July 24, 2000). The objective of this study is to address remaining spent nuclear fuel transportation issues from the Modal Study (DIRS 101828-Fischer et al. 1987, all) and the *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, all), using a public participation approach to solicit public and stakeholder interests in developing the study's scope and parameters for review. Further, whereas the earlier studies were analytical in nature, the Package Performance Study will consider the use of physical testing to address issues, where appropriate. Risk insights obtained using current analysis techniques, physical testing, and through interaction with stakeholders and the public, will support the Nuclear Regulatory Commission's ongoing efforts to ensure that its regulatory actions are sensitive to risk and effective.

M.4.3 RESULTS FROM PREVIOUS CRASH TESTS

U.S. laboratories, with British assistance, have staged severe truck and rail accidents to study the response of full-scale spent nuclear fuel casks. Those tests, which were designed primarily to verify computer models, yielded films and photographs that have been widely cited as strong evidence of nuclear waste transportation safety, because they illustrate the robustness of these casks in accidents. Sandia National Laboratories conducted four crash tests of U.S. spent nuclear fuel casks during 1977 and 1978 (DIRS 155792-Yoshimura 1978, all). In the first test, a truck carrying a 20-metric-ton (22-ton) cask was crashed into a hard, massive, earth-backed concrete wall at 97 kilometers (60 miles) per hour, causing very little damage to the cask. The same cask was loaded onto another truck and driven into the wall at 135 kilometers (84 miles) per hour, again causing minor cask damage. In the third test, a locomotive traveling 130 kilometers (81 miles) per hour struck a 23-metric-ton (25-ton) cask on a truck trailer that was parked across the tracks. The fourth test involved crashing a railcar carrying a 67-metric-ton (74-ton) spent nuclear fuel cask into the hard, massive, earth-backed concrete wall, and the same cask and railcar were then engulfed in a jet fuel fire. After about 90 to 100 minutes, or three times the duration of the regulatory test, the fire was stopped when evidence of damage to the shield casing was observed. Although the observed damage could have reduced shielding effectiveness, it would not have impaired containment capability. The tests were intended to verify computer simulation programs used for structural analysis. They were not intended to rigorously assess containment capability, nor were the casks instrumented to do so. The experts who conducted the tests, however, made some qualitative judgments about cask performance. According to Sandia, none of the tests would have released hazardous levels of radioactivity if the casks had contained spent nuclear fuel (DIRS 155792-Yoshimura 1978, all).

A British train crash demonstration, conducted in 1984, involved a locomotive weighing 140 metric tons (154 tons) pulling three 33-metric-ton (36-ton) passenger cars at 160 kilometers (100 miles) per hour. The train struck a British Magnox spent nuclear fuel cask weighing 48 metric tons (53 tons) that had been placed on the tracks in what was believed to be its most vulnerable position. The cask held 3 metric tons (3.3 tons) of steel bars meant to simulate spent nuclear fuel. According to a report on the demonstration, the cask was positioned "so that a valve would be in the impact zone and so that the wheels and tow-hook on the locomotive would inflict maximum damage to the lid bolts" (DIRS 155791-Blythe et al. 1986, all). Extensive monitoring of the demonstration indicated that almost no cask pressure was lost and that no radioactivity would have been released by the crash. Measurements showed that the train impact was substantially less severe than the impact of the 9-meter (30-foot) drop test onto an unyielding surface. A report on the British train crash demonstration concluded that computer models could predict crash forces on spent nuclear fuel casks "with a high degree of confidence" (DIRS 155791-Blythe et al. 1986, all).

M.5 Emergency Response

M.5.1 ROLES AND RESPONSIBILITIES

As with any emergency situation in their jurisdictions, state and Native Americans governments have the primary responsibility to respond to accidents involving radioactive materials and to protect the public health and safety. State, tribal, and local emergency response personnel are the first to respond to hazardous material accidents. On arriving at the scene, first responders determine the presence or identification of hazardous materials, cordon off contaminated areas, initiate protective actions, and call for assistance from other personnel as necessary. Local responders usually contact state or tribal public health agencies. Many of those agencies have personnel trained to conduct radiological tests at the site to determine if there has been a release of radioactive material.

State, Native American, and local governments can request assistance from Federal agencies. An extensive Federal program exists to assist states and tribes in the event of an accident involving spent nuclear fuel or high-level radioactive waste. Seventeen Federal agencies participate in the program and are available to assist, if requested. A Lead Federal Agency, as defined by the "Federal Radiological Emergency Response Plan" (61 *FR* 20944; May 8, 1996), is responsible for leading and coordinating Federal on-scene actions and assisting state, tribal, and local governments in determining measures to protect life, property, and the environment. If requested, the Lead Federal Agency would ensure that other Federal agencies assisted in implementing protective actions. The Lead Federal Agency can change for different stages of an emergency.

DOE is responsible for developing policy and guidance for emergency planning, management, training, and response to an accident involving its shipments. The Department has several programs available to provide assistance to state, Native American, and local governments in response to radioactive material accidents. The Radiological Assistance Program, for example, provides trained personnel with equipment to evaluate, assess, advise, and assist in the mitigation and monitoring of potential immediate hazards associated with a transportation accident. As part of the program, DOE maintains eight Regional Coordinating Offices across the country that are staffed 24 hours a day, 365 days a year. The staff consists of nuclear engineers, health physicists, industrial hygienists, public affairs specialists, and other personnel who provide field monitoring, sampling, decontamination, communications, and other services, as requested.

DOE's Radiation Emergency Assistance Center/Training Site (REAC/TS) focuses on providing rapid medical attention to people involved in radiation accidents. REAC/TS maintains a 24-hour response center to provide direct support, including deployable equipment and personnel trained and experienced in the treatment of radiation exposure, to assist Federal, state, tribal, and local organizations.

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M.5.2 ACTIONS TAKEN IN AN EMERGENCY SITUATION

During an emergency in which the carrier or escorts could communicate through the satellite tracking system or by phone if the system was not available, the carrier would contact DOE, and DOE would contact the state or tribe (who would contact the local responders), the Nuclear Regulatory Commission, and the U.S. Department of Transportation. When the first responders arrived, the carrier would assist as outlined in its emergency response plan. The first responders would investigate the potential presence of radioactive material, treat injuries, protect themselves and the public, and secure the area. As noted above, first responders would determine further appropriate emergency response actions, because they would be in charge of the accident scene. The roles and responsibilities of those who would respond to requests for assistance are described above.

If neither the carrier nor the escorts could communicate, the first responders arriving at the scene would still have information available about the shipment, such as the name of the shipper, the type of material being transported, and the telephone number to call in an emergency. This information would have been provided to the state, tribal government, or local law enforcement personnel in accordance with Nuclear Regulatory Commission regulations during the preshipment planning process and in the advance notification of shipments. In addition, the information would be available in the shipping papers accompanying the shipment, and from the labels, markings, and placards associated with the shipment. The first responders would assess the accident scene and call for state, tribal, and Federal assistance as necessary.

M.6 Technical Assistance and Funding of Emergency Response Training for Local and Native American Governments

Section 180(c) of the NWPA requires DOE to provide technical assistance and funds to states for training public safety officials of appropriate units of local and Native American governments through whose jurisdictions the Department planned to transport spent nuclear fuel or high-level radioactive waste. The training of public safety officials would cover procedures required for safe routine transportation of these materials and for dealing with emergency response situations.

DOE is responsible for implementing Section 180(c). DOE published a Notice of Revised Proposed Policy and Procedures (63 *FR* 23753; April 30, 1998) based on comments received on several previous *Federal Register* notices. In the Proposed Action proceeded, DOE would either update the Policy and Procedures as a Final Policy, or could promulgate regulations.

The following list provides selected highlights of the Notice of Revised Proposed Policy and Procedures:

- DOE would implement Section 180(c) through a grants program. DOE would administer the grants, which would be specific to the Section 180(c) program. The Department would adopt, to the extent practicable, any future DOE-wide standardization of assistance to states and tribes for the Department's radioactive materials shipments. This could include standardization of funding mechanisms, training standards, equipment purchases, and definition of technical assistance.

- DOE anticipates that it would know approximately 5 years before shipments occurred, the states or Native American, lands through which the shipments would travel, even if exact routes had not been selected. Using this information, DOE would notify those jurisdictions about their eligibility under Section 180(c).

- DOE has expanded eligibility to include those jurisdictions where a route carrying spent nuclear fuel and high-level radioactive waste shipments constitutes the border between two jurisdictions (for example, between a state and tribal lands, or between two states).

- For emergency response procedures, DOE would provide funding and technical assistance to eligible jurisdictions to address incremental training requirements resulting from spent nuclear fuel and high-level radioactive waste shipments. Specifically, the Department would provide funding and technical assistance for eligible jurisdictions to obtain and maintain awareness-level training for local response jurisdictions in the increment specific to radioactive materials shipments. In addition, to the extent funds were available, the assistance could be used to obtain an enhanced level of emergency response capability to include operations-level training, technical-level training, and the corresponding refresher training, all in an increment specific to radioactive materials shipments.

- For safe routine transportation procedures, DOE would provide funding and technical assistance to eligible jurisdictions to prepare for safety and enforcement inspections of spent nuclear fuel and high-level radioactive waste shipments and for access to satellite tracking information.

- The application process should take about a year. A one-time planning grant of $150,000 would be provided to eligible states and tribal jurisdictions for determining training and funding needs and for preparing an application in about 2006 (4 years before shipments began). DOE expects the application to include a 5-year plan detailing how the funds would be spent each year. In about 2007, the base grant for planning and coordination would be provided. In about 2008 to 2010, funds would be provided for training and the purchase of equipment. Local governments could not receive Section 180(c) grants or technical assistance directly from DOE.

- DOE would allow a variety of activities that an applicant might consider appropriate for training under Section 180(c). For example, it would be the applicant's decision who received training and which organization would administer the training. The Notice of Revised Proposed Policy and Procedures strengthens the requirement that first responders be the recipients of the awareness-level training. In addition, an applicant would be able to budget as much as 25 percent of its total Section 180(c) funds to purchase appropriate (training-related) equipment for the 2 years prior to shipment. After that, the applicant would be able to budget as much as 10 percent of the total Section 180(c) funds to purchase equipment.

M.7 Physical Protection of Spent Nuclear Fuel in Transport

Spent nuclear fuel contains small concentrations of fissile plutonium (generally less than 1 percent). If chemically separated from the spent nuclear fuel and refined, some of this plutonium could be used to produce explosive nuclear devices. To protect against this potential, regulations are established to ensure protection of shipments from illegal diversion. Because the fissile material is in low concentration and a difficult-to-retrieve form, the threat of diversion of a spent nuclear fuel shipment to obtain these materials would be slight.

In addition, shipments must be protected from sabotage. Initial studies of the effects of sabotage on spent nuclear fuel casks suggested the possibility of severe consequences. Although later studies and experiments found these initial studies to overpredict potential consequences, these initial predictions led the Nuclear Regulatory Commission to develop a set of rules specifically aimed at protecting the public from harm that could result from sabotage of spent nuclear fuel casks. Known as physical protection or safeguard regulations (10 CFR 73.37), these security rules are distinguished from other regulations that deal with issues of safety affecting the environment and public health. The objectives of the safeguard regulations are to:

- Minimize the possibility of sabotage
- Facilitate recovery of spent nuclear fuel shipments that could come under control of unauthorized persons

To achieve these objectives, the Nuclear Regulatory Commission safeguard rules require:

- Advance notification of each shipment to the Nuclear Regulatory Commission, the states, and Native American governments (see Section M.2.5)
- The licensee to have current procedures to cope with safeguard emergencies
- Instructions for escorts on how to determine if a threat exists and how to deal with it
- Maintenance of a communications center to continually monitor the progress of each shipment
- A written log describing the shipment and significant events during the shipment
- Advance arrangements with law enforcement agencies along the route
- Advance route approval by the Nuclear Regulatory Commission
- Avoidance of intermediate stops to the extent practicable
- At least one escort to maintain visual surveillance of the shipment during stops
- Shipment escorts to report status on a regular basis
- Armed escorts in heavily populated areas
- Onboard communications equipment
- Protection of specific shipment information

The expected threat of sabotage is based on several factors, including the desirability of attacking a spent nuclear fuel cask, availability of devices that a saboteur could use and the portability of such devices, skills required to use selected devices, and capability of the device to damage a robust spent nuclear fuel cask.

The safety features included in the design of a spent nuclear fuel cask that provide containment, shielding, and thermal protection also provide protection against sabotage. The casks would be massive. The spent nuclear fuel in a cask would typically be only about 10 percent of the gross weight; the remaining 90 percent would be shielding and structure.

Specific test programs have been conducted (DIRS 156313-Sandoval et al. 1983, all; DIRS 101921-Schmidt, Walters, and Trott 1982, all) to determine the nature and quantities of material that could be released from a spent nuclear fuel cask in sabotage events. These test programs confirmed that earlier studies (DIRS 155054-Finley et al. 1980, all) over-predicted potential consequences. The results of the

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tests indicate that the regulations, which were based on the earlier, more conservative estimates, are adequate to protect the public.

The Nuclear Regulatory Commission, along with other Federal agencies, continually monitors and evaluates threat assessments, which would enable revision of the regulations, if necessary.

M.8 Liability

The Price-Anderson Act [Section 170 of the Atomic Energy Act, as amended (42 U.S.C. 2011 *et seq.*)] provides indemnification for liability for nuclear incidents that apply to the proposed Yucca Mountain Repository. The following sections address specific details or provisions of the Act.

M.8.1 THE PRICE-ANDERSON ACT

In 1957, Congress enacted the Price-Anderson Act as an amendment to the Atomic Energy Act to encourage the development of the nuclear industry and to ensure prompt and equitable compensation in the event of a nuclear incident. Specifically, the Price-Anderson Act establishes a system of financial protection for persons who may be liable for and persons who may be injured by a nuclear incident. The purpose of the Act was (1) to encourage growth and development of the nuclear industry through the increased participation of private industry, and (2) to protect the public by ensuring that funds are available to compensate victims for damages and injuries sustained in the event of a nuclear incident. Congress renewed and amended the indemnification provisions in 1966, 1969, 1975, and 1988. The 1988 Price-Anderson Amendments Act extended the Act for 14 years until August 1, 2002 (Public Law 100-408, 102 Stat. 1066). DOE has recommended that Congress extend the Act in substantially the same form [see *Report to Congress on the Price-Anderson Act* (DIRS 155789-DOE 1999, all)].

M.8.2 INDEMNIFICATION PROVIDED BY THE PRICE-ANDERSON ACT

DOE must include an agreement of indemnification in each DOE contract that involves the risk of a nuclear incident. This indemnification (1) provides omnibus coverage of all persons who might be legally liable, (2) indemnifies fully all legal liability up to the statutory limit on such liability (currently $9.43 billion for a nuclear incident in the United States), (3) covers all DOE contractual activity that could result in a nuclear incident in the United States, (4) is not subject to the usual limitation on the availability of appropriated funds, and (5) is mandatory and exclusive.

M.8.3 LIABILITY COVERED AND LIABILITY EXCLUDED BY THE INDEMNITY

The Price-Anderson Act indemnifies liability arising out of or resulting from a nuclear incident or precautionary evacuation, including all reasonable additional costs incurred by a state or a political subdivision of a state, in the course of responding to a nuclear incident or a precautionary evacuation. It excludes (1) claims under state or Federal worker compensation acts of employees or persons indemnified who are employed at the site of and in connection with the activity where the nuclear incident occurs, (2) claims arising out of an act of war, and (3) claims involving certain property located on the site.

M.8.4 DEFINITION OF A NUCLEAR INCIDENT UNDER THE PRICE-ANDERSON ACT

A *nuclear incident* is any occurrence, including an extraordinary nuclear occurrence, causing bodily injury, sickness, disease, or death, or loss of or damage to property, or loss of use of property, arising out of or resulting from the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material (42 U.S.C. 2014).

M.8.5 PROVISIONS FOR A PRECAUTIONARY EVACUATION

A *precautionary evacuation* is an evacuation of the public within a specified area near a nuclear facility or the transportation route in the case of an accident involving transportation of source material, special nuclear material, byproduct material, spent nuclear fuel, high-level radioactive waste, or transuranic waste. It must be the result of an event that is not classified as a nuclear incident but poses an imminent danger of injury or damage from radiological properties of such nuclear materials and causes an evacuation. The evacuation must be initiated by an official of a state or a political subdivision of a state who is authorized by state law to initiate such an evacuation and who reasonably determined that such an evacuation was necessary to protect the public health and safety.

M.8.6 AMOUNT OF INDEMNIFICATION

The Price-Anderson Act establishes a system of private insurance and Federal indemnification to ensure compensation for damage or injuries suffered by the public in a nuclear incident. The current amount of $9.43 billion reflects a threshold level beyond which Congress would review the need for additional payment of claims in the case of a nuclear incident with catastrophic damage. The limit for incidents occurring outside the United States is $100 million and requires the nuclear material to be owned by and under contract with the United States.

M.8.7 INDEMNIFIED TRANSPORTATION ACTIVITIES

DOE indemnifies any nuclear incident arising in the course of any transportation activities conducted in connection with a DOE contractual activity, including transportation of nuclear materials to and from DOE facilities.

M.8.8 COVERED NUCLEAR WASTE ACTIVITIES

The indemnification specifically includes nuclear waste activities that DOE undertakes involving the storage, handling, transportation, treatment, disposal of, or research and development on spent nuclear fuel, high-level radioactive waste, or transuranic waste. It covers liability for accidents that could occur while spent nuclear fuel and high-level radioactive waste was in transit from nuclear powerplants to the proposed repository, at a storage facility, or at the repository. If a DOE contractor or other person indemnified was liable for the nuclear incident or a precautionary evacuation resulting from its contractual activities, that person would be indemnified for that liability. While DOE's own tort liability would be determined under the Federal Tort Claims Act, DOE could use contractors to transport spent nuclear fuel and high-level radioactive waste and to construct and operate a repository, if such a repository was approved under the NWPA. Moreover, if public liability arose out of nuclear waste activities funded by the Nuclear Waste Fund subject to a DOE agreement of indemnification, compensation must be paid from that fund up to the maximum amount of protection. The Fund, established by the NWPA, pays for DOE activities involved with the proposed repository.

M.8.9 STATE, NATIVE AMERICAN, AND LOCAL GOVERNMENT PERSONS WHO ARE INDEMNIFIED

State, Native American, and local governments are included among the "persons" who may be indemnified if they incur legal liability. A *person* includes "(1) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than [DOE or the Nuclear Regulatory] Commission, any state or any political subdivision of, or any political entity within a state, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (2) any legal successor, representative, agent, or agency of the foregoing" (42 U.S.C. 2214). A state or a political subdivision of a state may be entitled to be indemnified for legal liability, including all reasonable additional costs incurred in the course of responding to a nuclear incident or an authorized precautionary evacuation. In addition, indemnified persons could include contractors, subcontractors, suppliers, shippers, transporters, emergency response workers, health professional personnel, workers, and victims.

M.8.10 PROCEDURES FOR CLAIMS AND LITIGATION

Numerous provisions ensure the prompt availability and equitable distribution of compensation, including emergency assistance payments, consolidation and prioritization of claims in one Federal court, channeling of liability to one source of funds, and waiver of certain defenses in the event of a large accident. The Price-Anderson Act authorizes payments for the purpose of providing immediate assistance following a nuclear incident. In addition, it provides for the establishment of coordinated procedures for the prompt handling, investigation, and settlement of claims resulting from a nuclear incident.

M.8.11 FEDERAL JURISDICTION OVER CLAIMS

The U.S. District Court for the district in which a nuclear incident occurs shall have original jurisdiction "with respect to any [suit asserting] public liability...without regard to the citizenship of any party or the amount in controversy" [42 U.S.C. 2210(n)]. If a case is brought in another court, it must be removed to the U.S. District Court with jurisdiction upon motion of a defendant, the Nuclear Regulatory Commission, or DOE.

M.8.12 CHANNELING LIABILITY TO ONE SOURCE OF FUNDS

The Price-Anderson Act channels the indemnification (that is, the payment of all claims arising from the legal liability of any person for a nuclear incident) to one source of funds. This "economic channeling" eliminates the need to sue all potential defendants or to allocate legal liability among multiple potential defendants. Economic channeling results from the broad definition of "persons indemnified" to include any person who may be legally liable for a nuclear incident. Thus, regardless of who is found legally liable for a nuclear incident resulting from a DOE contractual activity or Nuclear Regulatory Commission-licensed activity, the indemnity will pay the claim.

In the hearings on the original Act, "the question of protecting the public was raised where some unusual incident, such as negligence in maintaining an airplane motor, should cause an airplane to crash into a reactor and thereby cause damage to the public. Under this bill, the public is protected and the airplane company can also take advantage of the indemnification and other proceedings" (DIRS 155789-DOE 1999, p.12).

M.8.13 STATE TORT LAW ESTABLISHES LEGAL LIABILITY

Legal liability is not defined in the Price-Anderson Act, but the legislative history indicates clearly that state tort law determines what legal liabilities are covered (DIRS 155789-DOE 1999, p. A-6). In 1988, "public liability action" was defined to explicitly state that "the substantive rules for decision in such action shall be derived from the law of the state in which the nuclear incident involved occurs, unless such law is inconsistent with the provisions of [Section 2210 of Title 42]" (42 U.S.C. 2014).

M.8.14 PROVISIONS WHERE STATE TORT LAW MAY BE WAIVED

The Price-Anderson Act includes provisions to minimize protracted litigation and to eliminate the need to prove the fault of or to allocate legal liability among various potential defendants. Certain provisions of state law may be superseded by uniform rules prescribed by the Act, such as the limitation on the awarding of punitive damages. In the case of an extraordinary nuclear occurrence (that is, any nuclear incident that causes substantial offsite damage), the Act imposes strict liability by requiring the waiver of any defenses related to conduct of the claimant or fault of any person indemnified. Such waivers would result, in effect, in strict liability, the elimination of charitable and governmental immunities, and the substitution of a 3-year discovery rule in place of statutes of limitations that would normally bar all suits after a specified number of years.

M.8.15 COVERAGE AVAILABLE FOR ACCIDENTS IF THE PRICE-ANDERSON ACT DOES NOT APPLY

If an accident does not involve the actual release of radioactive materials or a precautionary evacuation is not authorized, Price-Anderson indemnification does not apply. If the Price-Anderson Act indemnification does not apply, liability is determined under state law, as it would be for any other type of transportation accident. Private insurance could apply. As noted above, however, all DOE contracts for transportation of spent nuclear fuel and high-level radioactive waste to a repository would be covered by the Price-Anderson Act for nuclear incidents and precautionary evacuation. Persons indemnified under that DOE contractual activity would include the contractors, subcontractors, suppliers, state, Native American, and local governments, shippers and transporters, emergency response workers and all other workers and victims.

Carriers may have private insurance to cover liability from a non-nuclear incident and for environmental restoration for such incidents. All motor vehicles carrying spent nuclear fuel or high-level radioactive waste are required by the Motor Carrier Act, (42 U.S.C. 10927), and implementing regulations (49 CFR Part 387), to maintain financial responsibility of at least $5 million. Federal law does not require rail, barge, or air carriers of radioactive materials to maintain liability coverage, although these carriers often voluntarily cover such insurance. Private insurance policies often exclude coverage of nuclear accidents. Thus, private insurance policies only apply to the extent that Price-Anderson is not applicable.

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Appendix N

Are Fear and Stigmatization Likely, and How Do They Matter

Robert E. O'Connor studies the origins and consequences of risk perceptions. In the past 4 years his work has appeared in *Risk Analysis, Journal of Risk Research, Risk — Health, Safety, & Environment, Risk Decision and Policy, Public Understanding of Science, Social Science Quarterly, and American Journal of Political Science.* The U.S. Environmental Protection Agency is funding his present research on the development and application of ecological and socioeconomic indicators for integrated assessment of aquatic ecosystems of the Atlantic Slope in the Mid-Atlantic States.

O'Connor earned his doctorate in political science from the University of North Carolina and his undergraduate degree from Johns Hopkins University. Currently on leave from the Political Science Department at Pennsylvania State University, Dr. O'Connor is directing the Decision, Risk, and Management Sciences Program at the National Science Foundation.

ARE FEAR AND STIGMATIZATION LIKELY, AND HOW DO THEY MATTER

Lessons from Research on the Likelihood of Adverse Socioeconomic Impacts from Public Perceptions of the Proposed Yucca Mountain Repository

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The report summarizes the research on perception-based impacts and stigma effects and uses this research to assess qualitatively the likelihood that perceptions of danger and of stigma, regardless of whether they are based on accurate scientific assessments, might result in adverse socioeconomic impacts on Nevada, particularly the Las Vegas area.

There is a consensus among social scientists that a quantitative assessment of the potential impacts from risk perceptions of the repository and the transportation of spent nuclear fuel and high-level radioactive waste is impossible at this time and probably unlikely even after extensive additional research. The implication is not that impacts would probably be large, but simply difficult to quantify. Social scientists do not know enough to identify what would be the level of concern during the operation of a repository. Similarly, we cannot specify the links between those attitudes and individual decisions that would have socioeconomic impacts. Based upon what we do know from surveys and from analogues, we can assess qualitatively what outcomes seem most likely.

Effects from Perceptions of the Proposed Repository
In the absence of a large accident at the repository or a continuing series of smaller accidents, there is little reason to expect adverse effects:

- Although, when asked, many people report that they think of nuclear things as dangerous, these attitudes are usually not salient in people's lives and therefore do not influence personal decisions.

- Yucca Mountain is 90 miles from Las Vegas.

- Studies show few indications of adverse socioeconomic effects (and many positive socioeconomic effects) in places that currently safely store or dispose of radioactive waste.

- People who choose to vacation in Las Vegas are less likely to be concerned about the repository than people who choose to vacation elsewhere. Opening a repository, if there is any impact, would likely reinforce the preferences of people who do not intend to visit Las Vegas with or without an operating repository 90 miles away. People who like to visit Las Vegas would likely pay little attention.

- If the repository would be such a powerful disincentive to investors, businesses considering relocating to southern Nevada, and retirees and others considering relocating in the area, some effects of those perceptions should already be apparent. It is widely known that Congress has ordered DOE to characterize Yucca Mountain for consideration for a repository and that key program documents suggest that the site may be acceptable. If the proposed repository is such a powerful disincentive, prudent investors, facing a possible opening of the repository, would not

be investing in southern Nevada. Similarly, we would see a decline in population in southern Nevada as businesses and people decide to settle elsewhere in anticipation of future risks and stigma. There is no evidence of this behavior. Indeed, the opposite is true.

The assessment that substantial adverse socioeconomic impacts from perceptions of the repository are quite unlikely assumes that operations at the facility will not have either a major accident (e.g., an explosion with a significant release of ionizing radiation bringing about exposures downwind, some cases of radiation poisoning, and deaths) or periodic smaller accidents (e.g., damaged canisters with some releases of ionizing radiation). These events would most likely raise fears about the repository, make the repository salient to people in southern Nevada, result in some social amplification of risk, and perhaps even stigmatize the region. Adverse socioeconomic effects from perceptions of an accident-prone repository might be substantial even with the repository 90 miles away. Without nuclear accidents at Yucca Mountain, these effects are quite unlikely.

Effects from Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste
Absent accidents, there is no reason to expect impacts for property owners in areas beyond the transportation corridors. Even absent accidents, however, two studies report that, at least temporarily, a decline in residential property values of approximately 3 percent may be expected in transportation corridors in urban areas. Data from other transportation experiences (e.g., transuranic waste to WIPP) suggest that impacts on property values might be negligible or nonexistent. More research on whether property values have fluctuated with the transportation of radioactive materials would be beneficial, although the research would not allow analysts to know with certainty whether there would be any impacts from perceptions of shipments of spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository, or how long such impacts would persist.

Are Fear and Stigmatization Likely, and How Do They Matter?

Lessons from Research on the Likelihood of Adverse Socioeconomic Impacts from Public Perceptions of the Proposed Yucca Mountain Repository

1.0 Introduction

1.1 Background

In 1982, Congress passed the Nuclear Waste Policy Act (NWPA) to provide a framework for managing the nation's spent nuclear fuel and high-level radioactive waste. In 1987, Congress significantly amended the Act. These amendments directed the Secretary of Energy to study only Yucca Mountain as the site for a potential monitored geologic repository and, after completion of the studies, to recommend whether the President should approve the site for development as a repository. In response to the Act, the U.S. Department of Energy (DOE) has maintained a program of investigations and evaluations to assess the suitability of the Yucca Mountain site as a geologic repository, and to provide information for the environmental impact statement (EIS) required by the NWPA to accompany any approval recommendation.

The National Environmental Policy Act of 1969 (NEPA) process for the Yucca Mountain site has included meetings with the public to scope what DOE should include in the EIS and, subsequently, the publication of the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (U.S. Department of Energy 1999) (Draft EIS) in July 1999 and the *Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (U.S. Department of Energy 2001) (Supplement) in May 2001. Many comments on the Draft EIS and the Supplement, including several from the State of Nevada, contend that DOE would strengthen the EIS by giving attention to the possible impacts of perceptions associated with the proposed repository and the transportation of spent nuclear fuel and high-level radioactive waste.

Several different individuals and organizations have examined the potential socioeconomic impact of perceptions. DOE sponsored some of this research itself. In addition, DOE has made funding available to the State of Nevada and to county governments in southern Nevada to hire experts to evaluate the DOE-funded research as well as to conduct their own studies. As a result, there is a substantial body of literature that has explored possible socioeconomic impacts of perceptions about the proposed repository and transportation of spent nuclear fuel and high-level radioactive waste to such a repository.

Early in the site evaluation process for Yucca Mountain, the State of Nevada suggested a potential for perception-based impacts to cause adverse effects to the socioeconomic environment of the State of Nevada. The State's concern was:

- If many people perceive significant risks to themselves associated with the transportation and disposal of spent nuclear fuel and high-level radioactive waste, and
- If those risk perceptions then influence individual behavioral decisions, then

- Nevada, and particularly the Las Vegas area, will become a less attractive location for vacations, relocation of individuals and families, and business investments and relocations.

The concern, at its most extreme, is that perceptions of the Las Vegas area as a dangerous place could bring about a mass stigmatization of the Las Vegas area as a place that people should avoid. This mass stigmatization could then lead to a collapse of the tax base of southern Nevada.

In 1986, the State of Nevada initiated research on these "special effects" to "... devise methods for characterizing and estimating the potential for this unique class of impacts" (Loux 2000, 4). Since 1986 the State of Nevada and, more recently, some of the counties and cities in southern Nevada have commissioned studies that have explored the potential impact of risk perceptions.

During the same period, the DOE kept abreast of the research reported by the State of Nevada and sponsored its own research efforts, primarily through Argonne National Laboratory. These efforts resulted in an annotated bibliography (Nieves et al., 1990) of the literature regarding socioeconomic impacts associated with perceived risks, as well as several research reports and articles prepared by scientists at Argonne National Laboratory.

In the mid-1990s two summaries of what social scientists knew at that time about the potential impacts of risk perceptions appeared. Both projects were independent of DOE.

- In 1995 the Nuclear Waste Technical Review Board (NWTRB) produced one of the summaries, drawing upon NWTRB staff resources as well as the results of a 2-day meeting with ten social scientists who had researched risk perceptions related to radioactive materials. The NWTRB, which Congress established in the NWPA to evaluate the technical and scientific validity of site characterization activities, wanted to develop a better understanding of the relevant issues and questions and to ascertain if they adequately could be addressed and assessed in the context of the potential repository at Yucca Mountain (NWTRB 1995b, 6-7).

- In 1997, Doug Easterling, who had participated in a number of the State of Nevada's research efforts, produced the second summary of the potential impacts of risk perceptions. He published in *Risk Analysis* a review of studies produced by the State of Nevada and others.

The NWTRB and Easterling reviews established a baseline, as of 1997, of the available research in the field of perception-based impacts and stigma effects. This report will draw upon their findings as well as the results from more recent work.

During the scoping process for the Draft EIS, DOE received comments on the need to address perception-based impacts and stigma effects in the EIS. Guided by the conclusions reached by the NWTRB summary and the Easterling article, and by its own research, DOE decided at that time that, while the possibility of such negative impacts cannot be dismissed as entirely impossible, the state of the science was not sufficiently advanced to anticipate and measure the occurrence or extent of such impacts with any reasonable degree of accuracy. Therefore, results of these types of analyses would be so uncertain or speculative that they would not provide any meaningful input for decision-makers.

Because of the nature of the comments received on the Draft EIS and the Supplement to the Draft EIS, DOE has elected to reexamine the relevant literature and assess the state of the research into perception-based impacts and stigma effects.

1.2 Purpose

The purpose of this paper is to summarize the research on perception-based impacts and stigma effects and to use this research to assess qualitatively the likelihood that perceptions of danger and of stigma, regardless of whether they are based on accurate scientific assessments, could result in adverse socioeconomic impacts on Nevada, particularly the Las Vegas area.

1.3 Data

This report does not involve the collection of new data gathered specifically for this effort. The author reviewed the available literature, including work supported by DOE, the State of Nevada, and others.

1.4 Scope and Organization

After the introductory section, Section 2 describes the research literature related to possible effects from perceptions. The section reviews two documents that summarize findings (the 1995 NWTRB report and the 1997 Easterling article) and significant research published since those summary works.

Then, Section 3 assesses the ability of social scientists to estimate the likelihood, based upon the literature, that people in Nevada would feel threatened by the repository if it is constructed and operated at Yucca Mountain. Also, the section assesses possible risks related to transportation of spent nuclear fuel and high-level radioactive waste along transportation corridors. Do social scientists know enough to estimate risk perception impacts with a high level of certainty? Based upon what we do know, what levels of risk perceptions seem most likely?

Section 4 assesses the likelihood that people who view the repository as risky and who say they would feel threatened would actually change their behavior because of fears of the repository. This is the link between expressed attitudes and behavior. Are social scientists certain that current expressed attitudes are good predictors of future behavior? In summary, can social scientists estimate with a high degree of confidence the impacts of the repository on risk perceptions, behavior, and the Nevada economy in general as well as on selected sectors such as tourism and gaming? Based upon what we do know, are significant impacts from perceptions likely?

Next, Section 5 assesses the likelihood of stigmatization of the region as a result of the repository and transportation of spent nuclear fuel and high-level radioactive waste, again using the NWTRB and Easterling work as baseline scholarship as well as drawing on more recent work. Do social scientists know enough to estimate the probability of stigmatization with a high level of certainty? Are people who are likely to stigmatize the region also likely to act upon their views? Based upon what we do know, is stigmatization likely? If stigmatization happens, will individuals change their behavior? What will be the most likely impacts on the economy as a whole, on particular sectors, and on property values along transportation routes? Based upon what we do know, are significant impacts likely?

Finally, Section 6 describes what the state-of-the-art of perception-based impacts allows us to conclude about these impacts and with what degree of certainty. Is quantitative risk assessment possible? What can we conclude about the likely impacts of perceptions about the repository program?

2.0 The Research Literature

2.1 Summaries Published in 1995 and 1997

This section first reports the findings from two documents, a 1995 NWTRB report and a 1997 article by Doug Easterling, that were not directly supported by funding from DOE. The authors of these documents sought to summarize what social scientists know about the possible effects of perceptions about the proposed repository and the shipment of spent nuclear fuel and high-level radioactive waste in the future. Then, the section reviews selected studies written since those summaries.

NWTRB Report to the U.S. Congress and the Secretary of Energy

On May 23 and 24, 1995, the NWTRB held a "Joint Meeting of the Panels on Risk and Performance Analysis and the Environment and Public Health" to discuss "Perceptions of Risk and Social and Economic Impacts" (NWTRB 1995b). Ten distinguished social scientists (Gilbert Bassett, Doug Easterling, Hank Jenkins-Smith, Stephen Kraus, Warner North, James Opaluch, Howard Schuman, Paul Slovic, Elaine Vaughan, and Lee Wilkins) examined the link between risk perception and socioeconomic impacts. These scholars represented a diverse range of social science disciplines and experience including economics, journalism, political science, psychology, sociology, and survey research. Some had received funding directly from DOE, some from the State of Nevada, and some from neither organization. The NWTRB sought to "ventilate the methodological, empirical, and analytic issues, the technical questions that would have to be addressed to reach a grounded and sound conclusion on the validity of the proposition" (NWTRB 1995b, 7) that "perceptions of risk associated with a repository lead to significant adverse social and economic effects" (NWTRB 1995b, 6).

Garry Brewer, chairperson of the NWTRB panels on Risk and Performance Analysis and the Environment and Public Health, ran the sessions that contributed to the NWTRB's annual *Report to the U.S. Congress and the Secretary of Energy* (NWTRB 1995a). He asked the social scientists to comment on the sequence that must occur in order for perceptions to lead to impacts that can be identified and mitigated or avoided. Brewer posited that, " ... the chain … begins with risk and risk perception, and works its way through behavior, and from behavior to impact, and from impact, in social and economic terms, to mitigation and compensation" (NWTRB 1995a, 3). The *Report* concluded:

- "What are the origins of risk perceptions?

  There is a strong understanding of what factors (attitudinal, demographic, cultural, knowledge) influence risk perceptions. Very little consensus has emerged about the relative importance of those factors" (NWTRB 1995a, 43).

- "What is the link between attitudes and behaviors?

  There appears to be only a modest link between attitudes, such as risk perceptions, and consequent behaviors" (NWTRB 1995a, 43). At the meeting, Brewer summarized, " ... it's very, very difficult, tenuous, risky, absent a real sensitive understanding of context, to go from one's best measured sense of risk perception to predicting behavior" (NWTRB 1995b, 64). Stephen Kraus agreed, "The bottom line is I came up with 80 or 90 studies that seemed to be good, fairly methodologically sound tests of this question, of do attitudes predict behavior, and the answer seems to be a definitive, sometimes" (NWTRB 1995b, 89).

- "How do individual behaviors translate into socioeconomic impacts?

The relationship between individual behaviors and socioeconomic impacts has almost exclusively been inferred from anecdotal or case study evidence. Should another anecdote or case suggest a contradictory conclusion, no basis currently exists for distinguishing among different interpretations.... Moreover, other environmental, economic, and social conditions or trends could influence the socioeconomic well-being of southern Nevada, making isolating the impacts associated with a future repository very difficult" (NWTRB 1995a, 43).

- "How are impacts evaluated? How can they be compensated for or mitigated?

  At the core of the compensation and mitigation issue are three questions: How do you know if some response is needed, especially for a project that will be implemented over the next century? How can any harm experienced be quantified in monetary terms? Are there certain types of harm that intrinsically cannot be compensated for or mitigated against either because of their nature or their magnitude? The social sciences have not yet provided very determinative answers to those questions" (NWTRB 1995a, 43).

The NWTRB concluded that, "Standard socioeconomic impacts have been analyzed in a variety of contexts using relatively standard methodologies.... Special socioeconomic effects, caused by perceptions of risk, are much more difficult to predict. Substantial theoretical, methodological, and conceptual obstacles need to be overcome before much confidence can be given to predictions of more than a few years" (NWTRB 1995a, 44).

Doug Easterling, "The Vulnerability of the Nevada Visitor Economy to a Repository at Yucca Mountain"

In 1997 *Risk Analysis* published Easterling's review of the "… studies commissioned by the Nevada Nuclear Waste Project Office to estimate the economic impact of a high-level nuclear waste repository at Yucca Mountain" (Easterling 1997, 635). The purpose of his article was to review the:

> "… socioeconomic research program undertaken by the NWPO [Nevada Nuclear Waste Project Office], outlining the research questions, methods, and findings from a variety of studies that examine the potential for visitor impacts. In general, these studies explore the question of whether a repository at Yucca Mountain would influence the decision to visit Nevada for a vacation, meeting, or convention.… Three distinct methodologies have been used to investigate visitor impacts: case studies, elicitation of behavioral intent, and theory testing…. The primary purpose of this paper is to describe what is known and what is not known and to help establish an agenda for future socioeconomic studies" (Easterling 1997, 636).

In addition to studies supported by the State of Nevada, the review recognized research commissioned by DOE, as well as research not sponsored by stakeholders.

Easterling describes the research commissioned by the State of Nevada as focused on three theories of visitor impact: risk-avoidance, negative imagery, and stigmatization. The "risk-avoidance" model is based on the standard theories of self-protective behavior; i.e., "… people avoid destinations they perceive to be risky" (Easterling 1997, 637). This model suggests that Nevada could suffer economic losses "… if potential visitors view the repository as a major hazard" (Easterling 1997, 637). Furthermore, the risk-avoidance theory suggests that "... the potential for economic losses increases if the repository is plagued by mishaps or mismanagement" and the effects might be compounded "... if repository-related concerns are highlighted by the media or interest groups" (Easterling 1997, 637). Regarding the construct of "negative imagery," Easterling states that researchers have assumed that the repository will work its way into the "image set" of places in the vicinity. "In other words, when people think of the prospect of visiting Las Vegas, the repository will become one of the images that comes to mind. The theory assumes that this image will be highly aversive for the typical individual, and as such, will reduce the decision-maker's preference for visiting Las Vegas" (Easterling 1997, 637). Easterling points out that the risk-avoidance and negative-imagery models represent independent and complementary pathways to influence visitor decisions. That is, the negative imagery model suggests that visitors might avoid any place they feel has an unpleasant or noxious image, regardless of whether they perceive that location to be risky. The risk-avoidance and negative-imagery models both suggest that impacts on visitor decisions would be exacerbated by serious repository-related accidents with extensive coverage by the media.

The third theory, "stigmatization" is characterized as "... the extreme case of either the risk-avoidance or negative-imagery process" (Easterling 1997, 638). Easterling notes that "Stigmatization is likely to require a rather extreme initiating event" such as a "... radiation release as extreme as the Chernobyl accident ... but stigmatization is less likely under more benign scenarios" (Easterling 1997, 638). However, "... even if stigmatization does not occur, the repository could marginally increase the perceived risk and/or imagery associated with the state, which might still impact visitor behavior" (Easterling 1997, 638).

In his review of the historic research, Easterling summarizes both the "Nevada studies" and the "counter-evidence studies" and indicates that the research commissioned by the State of Nevada "... suggests that there are instances in which nuclear facilities have led to losses in the visitor economy of nearby communities" (Easterling 1997, 639), but the counter-evidence studies imply that there is little cause to anticipate visitor impacts. Easterling explains,

> "Some of this contrast stems from a difference in what the researchers were intending to demonstrate. Namely, the Nevada studies specifically sought out cases where economic losses had occurred in order to show that repository-induced impacts were within the range of possibility, whereas Metz [William Metz, Argonne National Laboratory] selected a set of nuclear-weapons facilities that he thought would provide a best-guess estimate of the consequences of a repository" (Easterling 1997, 639).

In other words, the Nevada studies have focused on case studies of accidents that might result in risk avoidance, negative imagery, and/or stigmatization, while the counter-evidence studies have examined the average long-term performance of nuclear facilities. Easterling concludes that the "... primary lesson to draw from the case-study approach is that the impact of a nuclear facility on the local economy depends almost completely on the severity of the events that occur over the lifetime of the facility" (Easterling 1997, 639).

The second element of research examined in the article looks at studies of intended behavior. The State of Nevada sponsored a series of surveys designed to elicit statements of intended behavior from a variety of groups (e.g., the general public, persons who vacation in Nevada, convention planners and attendees). The intent of these studies was to assess possible repository-related effects on respondents' behavior by asking them to "... consider a variety of repository scenarios and indicate how they would behave" (Easterling 1997, 640). These studies invariably found that, based on statements of intended behavior, Nevada would become a less desirable place to visit, start a business, relocate, invest, etc. As Easterling observes, however, "Still, one must acknowledge that the link between stated intent and subsequent behavior is far from perfect" (Easterling 1997, 642). The long period between conducting the survey and opening the repository increases disparities between stated intentions and actual behavior.

Finally, the article turned to the third component of the research commissioned by the State of Nevada: studies to understand visitation decisions. The intent of this research was to test the three theories of visitor impact—risk avoidance, negative imagery, and stigmatization—to the degree possible in the absence of an operating repository. The research examined several propositions associated with these theories:

- Does perceived risk influence behavior?
- Would a repository increase perceived risk for Nevada?
- Does imagery influence visitation decisions?
- Is negative imagery associated with a repository?
- Will repository imagery be aligned with Nevada?

Easterling indicates that the answer to each of these propositions probably is affirmative. There is evidence that suggests risk perceptions influence behavior, perceived risk has remained high for the repository during the period of the studies, imagery does appear to influence visitation decisions, and the imagery associated with a repository largely is negative.

Easterling suggests caution, however, before accepting the proposition that reduced tourism and fewer conventions will occur because of negative imagery from the repository and shipments of spent nuclear fuel. If those individuals who already hold a negative image of Nevada (based on negative attitudes toward legalized gambling, for instance) are also disproportionately the same people who will develop a negative imagery of Nevada because of the repository, "... then we might see only a further alienation of Nevada among the state's detractors, not avoidance among persons who currently visit the state" (Easterling 1997, 645).

Easterling also urges caution regarding the last proposition, that people will necessarily associate the repository with Nevada. Now, when asked about their image of Nevada or Las Vegas, few respondents associate the repository with Nevada, perhaps because the facility has not yet been built. He also notes that the long history of the Nevada Test Site does not appear to be a "... prominent part of the public's mental landscape of Nevada, which calls into question the proposition that people will associate a Yucca Mountain repository with Nevada" (Easterling 1997, 644).

The conclusion of Easterling's review focuses on many of the uncertainties inherent in the studies that he evaluated. He notes that the studies have shown that a "... repository at Yucca Mountain could have a negative impact on Nevada's visitor economy, but this is a possibility rather than an inevitability" (Easterling 1997, 645). He observes that the case studies of analogous facilities have shown that visitors sometimes avoided areas near nuclear facilities, particularly following a well-publicized incident involving radioactive contamination, but those studies do not allow a reliable assessment of when such impacts occur or the magnitude of the impacts. Easterling states, "... the studies of intended behavior provide reason to believe that visitation decisions will be influenced by a repository (at least under severe scenarios), but these studies are subject to substantial imprecision" (Easterling 1997, 645). Regarding the tests of visitor-behavior theories, studies "... support the possibility of a repository leading to avoidance behavior, but uncertainties remain. We know that the perceived risk and imagery associated with a place have an influence on a person's likelihood of visiting that place, but we don't know how a repository at Yucca Mountain will influence the perceived risk and imagery associated with Nevada" (Easterling 1997, 645).

Easterling summarizes his review, "The bottom-line conclusion from these studies is that repository-induced impacts are possible, but uncertain. Furthermore, much of this uncertainty is irreducible" (Easterling 1997, 645). Under a benign scenario, with incident-free operation of the facility and dissipation of controversy, "... the repository would likely have a benign impact on decision-making. On the other hand, if one assumes a severe repository scenario—with a set of high-publicity accidents and controversies—there is a very real potential for significant visitor impacts, in the extreme stigmatizing Nevada as a contaminated place to be avoided. If two researchers make different assumptions about how the repository will perform, they will inevitably arrive at competing economic forecasts" (Easterling 1997, 645).

The conclusions of both independent reviews—the NWTRB Report and the Easterling article—are consistent. The researchers seem in agreement on several points:

- While the body of research, both directly associated with a potential Yucca Mountain repository and unrelated studies, is extensive, significant uncertainties regarding the crucial questions of the effects of public perceptions remain.

- The evidence suggests that there is some understanding of how perceptions are formed, that those perceptions might influence individual behavior, and that those individual behaviors collectively might in some instances lead to socioeconomic impacts. The understanding of those relationships, however, is limited and contextual.

- The repository and transportation of spent nuclear fuel and high-level radioactive waste would not necessarily have either substantial or negative socioeconomic effects from perceptions, although it is possible to conceive of circumstances that would bring about significant negative socioeconomic effects.

- Social scientists have a quite limited capability to measure accurately the occurrence, timing, and extent of socioeconomic effects from future perceptions. There is great uncertainty about (1) the nature and intensity of future perceptions related to the repository and the transportation of spent nuclear fuel and high-level radioactive waste if DOE built the repository, (2) the link of such perceptions to individual behavior, and (3) the link between individual behavior and socioeconomic impacts.

The next sections describe the research since 1997 to report fresh insights and to examine whether the conclusions of 1995 and 1997 require revision.

2.2 Description of Research Since 1997

Most of the research related to risk perceptions published since the Easterling article in 1997 is only tangentially related to the possible socioeconomic impacts of a repository and transportation of spent nuclear fuel and high-level radioactive waste. Much of the research has focused on developing a better understanding of the etiology of perceived risk. Scholars have looked to cultural theory (e.g., Shrader-Frechette 1997; Sj`berg 1998a; Marris, Langford, and O'Riordan 1998; Brenot, Bonnefous, and Marris 1998; Grendstad and Selle 2000; Langford et al. 2000), trust (e.g., Sj`berg and Drottz-Sj`berg 1997; Earle and Cvetkovich 1998; Peters, Covello, and McCallum 1998; O'Connor, Bord, and Fisher 1998; Greenberg and Williams 1999; Slovic 1999; Siegrist 2000; Siegrist and Cvetkovich 2000; Siegrist, Cvetkovich, and Roth 2000; Sj`berg 2001), the role of worry in risk perception (e.g., Sj`berg 1998b; Baron, Hershey, and Kunreuther 2000), and how perceptions of benefits influence risk perceptions (e.g., Slovic 2000; Finucane, et al. 2000). Other research has focused on risk communication (e.g., Long and Fischhoff 2000; Siegrist and Cvetkovich 2001; Chess 2001), the willingness to pay for "zero risk" (e.g., Burger et al. 1997; Nakayachi 1998), and how risky experiences change perceptions (e.g., Rogers 1997).

The authors of five studies published since the Easterling article intended their work to address issues of the socioeconomic effects of perceptions of the proposed repository. This section will review each of those studies in turn.

William Metz and David Clark, "The Effect of Decisions about Spent Nuclear Fuel on Residential Property Values"

In an article funded by DOE and published in the same 1997 issue of *Risk* Analysis as the Easterling article, William Metz and David Clark attempt to determine if property values in the vicinity of two nuclear power plant sites were affected by decisions at the facilities regarding spent nuclear fuel storage and extension of the permit to operate the reactors (Metz and Clark 1997). The data used in the study "... represent individual single-family residential property sales that took place between 1990 and 1994 within 15 miles of the Rancho Seco and Diablo Canyon nuclear plants" (Metz and Clark 1997, 574). The authors report their results: "... decisions and announcements about spent nuclear fuel storage activities have not affected the local residential property market to the extent predicted by surveys of attitudes and images. Our hedonic model results indicate that this finding of no property value effect is the case regardless of whether a plant is operating or closed or whether the high-level waste is to be placed in dry-cask storage facilities immediately or as part of a future action" (Metz and Clark 1997, 581). The authors do note, however, that "... these findings reflect only the current residential property value situation around the two California plant sites; we made no attempt to determine whether there were effects on residential property values at the time of the reactors' siting announcements and construction" (Metz and Clark 1997, 581).

The authors conclude that predictions based on surveys of public perceptions and images might overestimate negative economic effects as reflected in residential property values.

Hank Jenkins-Smith, "Modeling Stigma: An Empirical Analysis of Nuclear Images of Nevada

In 2001 Hank Jenkins-Smith published a chapter in *Risk, Media, and Stigma: Understanding Public Challenges to Modern Science and Technology,* edited by James Flynn, Paul Slovic, and Howard Kunreuther. Funded by DOE, Jenkins-Smith designed and implemented one survey with a national sample and a second survey with a longer questionnaire with residents of Phoenix, Arizona. He wanted to focus "on the processes by which individuals acquire images of different kinds, give value to them, and rely on them in development of preferences" (Jenkins-Smith 2001, 108). He sought to examine a general proposition:

> "… different kinds of individuals are quite likely to acquire and use distinct bundles of images. If this proposition is correct, when new kinds of images (e.g., nuclear ones) are introduced about that place, they are likely to be more readily acquired by some people than others, and once acquired are likely to be valued differently. If so, whether a new image will stigmatize to a place depends on how readily that image is acquired, how it is valued, and how it is attached to preferences for the place by individuals who would otherwise be attracted to that place" (Jenkins-Smith 2001, 108).

The findings of this study are important and worth quoting at length:

- "Some people are more likely to acquire nuclear images of Nevada than others….
- …. the valences attached to images about a place are very strong predictors of vacation preferences for that place. Thus, the more positive the valance of one's images about a place, the more likely it is that one will want to vacation there.
- The valances attached to images of a 'high level nuclear waste repository' appear to be reasonably valid measures of the positive and negative affect that people hold about a nuclear waste repository.

- Despite the implication of some scholars (e.g., Weart 1988) that nuclear imagery is overwhelmingly dread-filled, the valences that people attach to nuclear images of nuclear facilities have considerable variation, ranging from quite positive to quite negative.

- The valences that people attach to nuclear images are related to their cultural and ideological predispositions. Egalitarians and self-described liberals tend to have more negative nuclear image valences, and conservatives and fatalists tend to have more positive ones.

- Nuclear images are part of a broader set of images about Nevada, and the valences of nuclear images are correlated with the valences of other Nevada image categories. Those with more negative valences for nuclear images also tend to have more negative images about gambling, prostitution and entertainment.

- Valences of both nuclear and gambling images appear to be influenced by cultural biases. Egalitarians tend to give more negative valences to both gambling and things nuclear, while fatalists give more positive valences" (Jenkins-Smith 2001, 129).

Jenkins-Smith summarizes,

> "If a new and negative type image is widely introduced into the image sets of a place, the effect of that image on such activities as vacationing, relocating, and retiring will be in part dependent on how the new image is associated with images in the pre-existing image sets. If the new image (e.g., a nuclear image) is negatively associated with the valences of images that previously had served to attract people to the place (e.g., a pristine environment), then the nuclear image is likely to lead to greatest reduction in vacation preferences among precisely those people who used to be most attracted to the place. The wide dispersion of such an image might well result in a stigmatization among those people who used to be attracted to that place. If, on the other hand, the new image (e.g., a nuclear image) is positively associated with the valences of those images that previously had attracted people to the place (e.g., gambling), then the nuclear image will be most positive (or least negative) for those who are most likely to vacation in that place. Those who were least likely to vacation in the place before (those who assigned negative valences to gambling) are the ones for whom the new images will be most negative. In that case, people who didn't want to vacation there before will now want to vacation there even less" (Jenkins-Smith 2001, 130-131).

Louis Berger Group, Inc., Assessment of the Hazards of Transporting Spent Nuclear Fuel and High Level Radioactive Waste to the Proposed Yucca Mountain Repository Using the Proposed Northern Las Vegas Beltway

In 2000 the Louis Berger Group issued a report, *Assessment of the Hazards of Transporting Spent Nuclear Fuel and High Level Radioactive Waste to the Proposed Yucca Mountain Repository Using the Proposed Northern Las Vegas Beltway,* designed to assess quantitatively the economic impacts of high-level nuclear waste transportation. The study commissioned by the City of North Las Vegas states that the transport of spent nuclear fuel and high-level radioactive waste "... along the Northern Beltway could result in significantly lower levels of economic activity and property values in year 2020. These results are based on a comparison between a base forecast of employment and business activity in year 2020 and an assumption that the hazardous waste transport will alter the land use and industry in the study area" (Berger Group 2000, E-3). The assumption used to estimate the economic impacts is that, as a result of the perceived risks and stigma effects associated with radioactive waste transportation, "... no office development will take place in the study area" (Berger Group 2000, 94). The study projects demographic losses in population and related employment; economic losses for reduced sales activities and employment earnings; and losses in property, sales, and state business taxes. The Berger report also asserts that the economic losses in North Las Vegas would result in larger losses in Clark County through a multiplier effect. Such losses would be reflected in reduced sales activities, employment earnings, collections of Nevada State Business Tax, and sales taxes (Berger Group 2000, E-4).

Urban Environmental Research, LLC, Property Value Impacts from the Shipment of High-Level Nuclear Waste through Clark County, Nevada (2000), Clark County Property Value Report on the Effects of DOE's Proposal to Ship High Level Nuclear Waste to a Repository at Yucca Mountain (2001)

In 2000 Urban Environmental Research, LLC (UER) issued a report prepared for the State of Nevada. In 2001 UER expanded the 2000 report by adding a review of the literature on the effects of "adverse environmental conditions" on property values. The purpose of this research by UER was to estimate potential property value effects associated with transporting radioactive waste through Clark County. The design involved interviewing Clark County residents who live near potential transportation routes and a small number of experts involved in lending for real estate investments in southern Nevada. The public survey (subcontracted to the University of Nevada at Las Vegas) asked residents their views on property values, how shipments of radioactive waste might affect these values, and whether residents who did not own property would consider buying near such routes. The other survey asked a small number of professional appraisers and bankers their opinion about how shipments of radioactive waste would influence their behavior and what they estimated would be the effects on property values near routes used for the shipments.

Residents, appraisers, and bankers all expect property values to decline near routes used to transport spent nuclear fuel and high-level radioactive waste. UER concludes, based on the residential survey:

> "Nuclear waste transportation is highly likely to significantly and adversely impact property values at least up to 3 miles from the routes. The reluctance to purchase residential properties near shipment routes by most of the Clark County population will not only result in property values declining but also may adversely effect (sic) the housing industry in the Las Vegas Valley and the level of revenue flow to local governments" (UER 2001, 71).

The conclusion from the survey of appraisers and bankers is that the value of residential properties within one mile of the route might be anticipated to decrease from 2.0 to 3.5 percent while the value of commercial and industrial properties might be anticipated to decline from 0.5 to 3.0 percent. The numbers would be much higher if there were transportation accidents.

These survey findings are typical of those of earlier work that most people say they prefer not to locate near anything nuclear, including transportation routes. The specific UER figures, however, are similar to the findings of the research on actual property values for one of the three counties studied by Gawande and Jenkins-Smith, as noted below.

Gawande and Jenkins-Smith, "Nuclear Waste Transport and Residential Property Values: Estimating the Effects of Perceived Risks"

Rather than depend solely on survey data, Kishore Gawande and Hank Jenkins-Smith collected data on 9,432 real estate transactions in three South Carolina counties to model the effects of a series of highly publicized shipments of spent nuclear fuel to a storage facility at DOE's Savannah River Site. The study, funded by DOE and forthcoming in the *Journal of Environmental Economics and Management*, addressed the question of whether shipments of spent nuclear fuel reduced residential property values. Along with the data of actual real estate sales, Gawande and Jenkins-Smith designed and implemented a survey that showed that many South Carolinians thought that a train accident and the rupture of spent fuel containers was likely. A majority thought that, if an accident occurred, "the nuclear fuel containers would break open and allow radiation to escape" (Gawande and Jenkins-Smith 2001, 7). The conclusions of the study indicate mixed results regarding property values:

> "Our analysis indicates that property values have reacted in different ways to the shipments in the three counties. No declines were evident in predominantly rural Berkeley and Aiken Counties, while an economically and statistically significant decline was evident in more populous Charleston County" (Gawande and Jenkins-Smith 2001, 2).

In Charleston County, "After the shipments began, the net gain in value associated with being five miles away from the route relative to a property on the route was nearly 3% of the average home value" (Gawande and Jenkins-Smith 2001, 22). There were no discernable results in the two more rural counties. Based on the different results for the three counties, the authors urge caution when making generalizations about the effect of spent nuclear fuel shipments on housing values. Gawande and Jenkins-Smith conclude, "Our results, if confirmed in further studies, indicate that there may be important distributional consequences of such shipments that should be considered in policy making. These consequences include suppressed property values when the shipments are highly publicized, controversial, and the focus of claims about extreme risk, as occurred in South Carolina" (Gawande and Jenkins-Smith 2001, 23).

2.3 Conclusions Regarding the Research Conducted Since 1997

The research since the summary article by Doug Easterling in 1997 has not challenged the conclusions he reached. Little new evidence has been developed since 1997 to address the fundamental uncertainties and improve our ability to anticipate accurately the occurrence, timing, or extent of those effects. Significant uncertainties regarding the crucial questions of the effects of public perceptions remain. We do not have a good understanding of the linkages among attitudes, individual behavioral decisions, and socioeconomic impacts. We cannot conclude that negative socioeconomic effects from perceptions regarding a repository and transportation of spent nuclear fuel are likely, although we cannot totally rule out negative effects. Many of the hypotheses involve assumptions that the proposed repository is unique and that tragic accidents would occur at the facility or with transportation. Data are not available to test these hypotheses because the facility is not open. Therefore, although additional research can tantalize and suggest possibilities, it cannot directly address the fundamental uncertainties of possible perceptual effects from the repository and the transportation of spent nuclear fuel and high-level radioactive waste.

Scholars supported by both DOE and the State of Nevada seem in agreement that the limitations and uncertainties noted by Easterling in his review still exist. During the November 1999 public hearing on DOE's water rights applications for the Yucca Mountain Site Characterization Project, James Flynn, formerly the project manager for the State of Nevada's study team, addressed whether Easterling's claims remain valid. Testifying for the State of Nevada as an "expert in risk, stigmatization and social amplification of risk," Flynn confirmed that Easterling's conclusions remain valid: Perception-based impacts and stigma effects associated with the proposed repository at Yucca Mountain are possible but not inevitable, and much of the uncertainty is irreducible (State of Nevada Department of Conservation and Natural Resources 1999, 150, 195-8).

Some of the work since 1997 assumes adverse effects and tries to tally the cost. The Berger Group study (2000) is an example of this type of work. The major limitation of the Berger Group study is that their assumption that no office development would take place near the Northern Beltway begs the question of what would be the impact of the selection of the Northern Beltway as a transportation route. The report assumes that the stigmatization of the Northern Beltway would be so intense that no businesses would be willing to locate near the road. Assumptions are useful only to the degree that they reflect a basis in reality. While the Berger report provides a review of the perception-based impacts literature, the report provides little basis for the assumption that no office development will take place in the study area. Businesses (including business services, health services, communications, financial institutions, and legal, engineering, and management services) that serve a regional market and do not have to locate near a specific client or set of clients have the flexibility to choose a site based on the desire to avoid a stigmatized transportation artery. Still, there is no evidence in the literature that businesses would consider only the assumed stigma in making business office location decisions

The second problem with the Berger report is its overstatement of losses even if there were no new development in the transportation corridor. The study's baseline projections for 2010 and 2020 are based on land use master plans for the Northern Beltway area (Berger Group, Inc. 2000, 67) and a reasonable assumption that the types and mix of businesses attracted to the Northern Beltway area will be similar to those located near the recently completed Southern Beltway (Berger Group 2000, 75-76). While not explicitly stated in the report, some portion of the growth in the Northern Beltway area must be due to relocation of people and businesses from other parts of Clark County. This conclusion emerges from three lines of reason.

First, some of the people who will move to the Northern Beltway area are certain to come from elsewhere in Clark County. The Berger report projects a population increase of approximately 138,000 persons living within 2 miles of the Northern Beltway from 2010 to 2020 (Berger Group 2000, Tables 7-2 and 7-3). During the same period, Clark County and the University of Nevada, Las Vegas projects a total county population increase of approximately 331,000 (Riddel and Schwer 2000, p. 3). The Berger projected population increase along the 13-mile sector of the Northern Beltway is approximately 42 percent of the total projected population increase in the county. An increase in population for such a small area that contains such a large portion of the total increase in the county population does not appear to be reasonable unless it includes substantial relocation from other areas of Clark County.

Second, some of the new businesses along the Northern Beltway are certain to come from elsewhere in Clark County. Table 7-9 of the Berger Group report shows that many businesses in the Southern Beltway area had relocated from elsewhere in Clark County. There is no reason to assume that the same relocation activity pattern will not occur along the Northern Beltway. Such an activity is consistent with business location decisions to take advantage of new infrastructure.

A third reason for the overestimation of losses, even given the assumption that no firms would locate near the Northern Beltway, is that the report's conclusions require that businesses that decide not to locate near the Northern Beltway also not locate elsewhere in Clark County. The analysis and identification of losses (such as reduced tax revenues) are dependent on the assumption that businesses do not locate anywhere in the region where they would pay such taxes. Even if stigmatization of the transportation routes were to occur, businesses would still locate in Clark County. In such an instance, stigmatization would come into play only in terms of the selection of the specific site within the region.

In summary, the Berger Group report takes a worst-case assumption regarding stigma effects, an assumption not supported by any transportation-related stigma event in history. Within this scenario the report then overestimates negative impacts by ignoring the in-county nature of many individual and business location decisions.

The UER work also has limitations, although they are quite different from those of the Berger Group study. The major problem of the UER survey is with accepting the stated intentions as good predictors of behavior (and lower property values). One reason to expect a large attitude/behavior gap is the several years between the survey response and the actual transportation of radioactive waste if the repository were to be built. The longer the time between expressing an attitude and having the opportunity to act upon it, the weaker is the predictive capability of the attitude. Finally, although there are no systematic studies of the effects on transporting radioactive waste on residential property values (with the exception of the 2001 Gawande and Jenkins-Smith study), there is much evidence of high property values near nuclear facilities (see, for example, Metz, 1994). It is not obvious why Nevadans would act differently.

Social science research on perception effects has had some important advances since 1997. Jenkins-Smith (2001) has made an impressive start toward elaborating the stigma model developed initially by Slovic et al. (1991). Jenkins-Smith shows that a repository and shipments of radioactive waste are less likely to bring negative socioeconomic effects through stigma than the earlier model had suggested. The people most likely to stigmatize Las Vegas because of its proximity to Yucca Mountain are the same people who already stigmatize Las Vegas for other reasons. They have no intention of relocating to southern Nevada with or without the repository. Still, more research on how different people make risk perceptions salient is needed.

Another advance is the work of Gawande and Jenkins-Smith (2001), the first systematic study of impacts on property values from the transportation of spent nuclear fuel. Highly publicized shipments of foreign spent nuclear fuel apparently did depress housing prices near the train tracks in an urban county, but had no effect in two rural counties. This is an important case study that calls for replication in other communities where DOE transports spent nuclear fuel, and for validation of the duration of the depression on housing prices. The policy implications for compensation and mitigation could be significant, particularly if the depression was of long-lasting effect.

The work of Metz and Clark (1997) also contributed to a better understanding of effects related to perception-based impacts by studying actual cases. Their study and the Gawande and Jenkins-Smith article (2001) indicate that economic impacts in the form of effects on property values can occur in some, but by no means all, situations.

3.0 Risk Perceptions of the Repository and Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste

This section is a qualitative assessment, based upon the literature discussed above as well as studies cited only in this section, of the likelihood that people would feel threatened in Nevada, and particularly the Las Vegas area, by the repository and transportation of spent nuclear fuel and high-level radioactive waste through southern Nevada.

In assessing the likelihood that Nevadans would feel threatened by the repository or the transportation of spent nuclear fuel and high-level radioactive waste, a number of observations are relevant:

- **Although a large proportion of people, when asked, report negative images of nuclear facilities and say they are risky, there is only weak and problematic evidence that people would feel threatened by a radioactive waste repository 90 miles away.**

One problem with testing hypotheses regarding whether people would be fearful of vacationing or living 90 miles away from a high-level radioactive waste repository is that there is no such repository anywhere that would allow social scientists to gather data to test perceptual hypotheses. The best we can do is to ask people to imagine how they might feel and to reason from analogies.

When social scientists ask people what they think of a radioactive-waste disposal facility, many report negative images related to risk (e.g., Slovic et al. 1991). This finding is by no means the same as a finding that many people would feel threatened by the repository if it were to open. There are two criteria that must be met before people would feel threatened by the repository. First, the Yucca Mountain Repository would have to become salient so that people would accept information about it and care about that information. Second, the information about the repository would have to engender beliefs that the repository threatens them.

Regarding the salience criterion, Yucca Mountain seems likely to become salient to neither Nevadans nor potential vacationers. The Nevada Test Site has not been and is not now a salient part of the way most people think about southern Nevada. The proposed repository is not, despite extensive press coverage in Nevada and across the nation, part of the way most people think about southern Nevada. It is unclear why the operation of the proposed repository would necessarily make the repository salient to the people of Nevada and to potential vacationers.

Even if the repository becomes salient, survey data show that not everyone will necessarily become fearful of adverse effects from a facility that is 90 miles away (Jenkins-Smith, 2001). Analogues also show that nuclear facilities are by no means necessarily disincentives to investors or to businesses and people considering relocation to the area. The closest analogues we have to the proposed repository are low-level waste facilities, Federal nuclear reservations (e.g., Hanford), the Waste Isolation Pilot Project (WIPP), and nuclear power plants. Communities are thriving well within 90 miles of these facilities. Similarly, there is little evidence that these facilities have frightened actual or potential tourists. Disneyland is 35 miles from San Onofre, which has at-reactor storage of spent nuclear fuel. There is no evidence that this situation has either frightened tourists or deterred them from visiting Anaheim.

Unless there is a major accident (e.g., an explosion with a significant release of ionizing radiation bringing about exposures downwind, some cases of radiation poisoning, and deaths) or periodic smaller accidents (e.g., damaged canisters with some releases of ionizing radiation), there is little reason to expect a repository to be salient to more than a small minority of southern Nevada residents and visitors. Many people might continue to say that a repository is risky when asked, but a repository will not be a salient part of their thinking and they will not feel threatened.

- **Different people react to information about nuclear facilities differently. The people who visit Las Vegas now are disproportionately less likely to attend to information about the repository and be concerned than are people who choose to vacation elsewhere.**

The Jenkins-Smith study (2001) shows that not everyone is equally disposed to fear a repository. Las Vegas vacationers are disproportionately predisposed neither to attend to information about the repository nor to feel threatened by radioactive waste. The implication of this finding is that the tourist industry of southern Nevada is less vulnerable to adverse socioeconomic impacts from a radioactive waste repository than other places would be.

- **Although a large proportion of people, when asked, report negative images of shipments of spent nuclear fuel and high-level radioactive waste, it is not clear that a substantial number of people would feel threatened by such shipments.**

Social scientists have devoted less energy to studying perceptions regarding the transportation of spent nuclear fuel and high-level radioactive waste than regarding the proposed repository. Nevertheless, both Flynn et al. (1997) and Gawande and Jenkins-Smith (2001) provide strong evidence that people think a transportation accident both is likely to happen and, if there was an accident, likely to bring harm to the people who live near the location of the accident. These attitudes suggest a possibility that many people along transportation routes might feel threatened by the shipments, but this scenario is not inevitable. As with threatening feelings about a repository, there are two criteria that must be met to turn questionnaire responses that shipments of spent nuclear fuel and high-level radioactive waste are risky into perceptions that those shipments are threatening. First, the situation with routes and shipments would have to become salient so that people would attend to information about it and care about that information. Second, the information about the shipments would have to engender beliefs that the shipments are threatening.

Regarding the salience criterion, why transportation of spent nuclear fuel and high-level radioactive waste would necessarily become salient is not obvious. In the past 40 years, over 2,500 shipments of spent nuclear fuel have taken place around the country, most with little attention. Publicized disputes have occurred related to some shipments of radioactive waste, specifically those involving transuranic waste to the WIPP and foreign spent nuclear fuel. These shipments are probably the closest analogues to the Nevada situation. In the WIPP situation, incident-free shipments seem to have minimized both the salience and threat perceptions related to transportation of transuranic waste among residents along corridors (Thrower, Portner, and Holm, 2001). In the case of foreign spent nuclear fuel shipped to the Savannah River site, as noted in Section 2.2, there is evidence that many residents in the Charleston area of South Carolina did feel threatened by the shipments.

One interpretation of the data regarding transportation of radioactive waste draws heavily on the Charleston area study (Gawande and Jenkins-Smith, 2001). This understanding of risk perceptions regarding transportation is that, early in the operation of the repository, transportation could be salient to many residents who could also feel threatened. With incident-free shipments, over time these residents along transportation corridors can be expected to forget about the issue. A second interpretation of the data gives more weight to the ongoing experience of frequent shipments around the country with little public concern and views the Charleston area case study as an aberration. This second understanding of risk perceptions regarding transportation is that few people along the routes are likely to notice or to care.

4.0 Linking Risk Perceptions to Behavior

This section reviews the literature linking risk perceptions to behavior, with particular attention to assessing whether attitudes about the repository and the transportation of spent nuclear fuel and high-level radioactive waste are likely to influence individual decisions.

- **Attitudes are usually poor predictors of behavior.**

Sidney Kraus (1995) published a meta-analysis of studies relating attitudes to behavior. He concluded that, at best, attitudes only sometimes strongly relate to behavior. Attitudes are good predictors of behavior only when a number of specific criteria are realized. These criteria include great specificity of the attitude and behavior, a short time between the solicitation of the attitude and the behavior, and the high potency of the attitude.

“Which presidential candidate are you going to vote for in tomorrow’s election?” will predict well; “Are you likely to move if, 4 years from now, the government puts in a hazardous-waste incinerator in the town?” is not a good predictor. The second question involves a considerable gap in time between the elicitation of the attitude and the decision. Also, voting is a low-cost decision whereas whether to move is more difficult.

High potency means that the attitude is strong and important to the respondent because of how it was acquired. Two people might give similar negative responses to questions about Health Maintenance Organizations (HMOs). One person reached that view because of comments from friends and late-night television comedians. The other person arrived at that same attitude because of numerous personal negative experiences with an HMO. The latter is much more likely to take action.

Questions that elicit attitudes that are socially desirable often fail to measure the attitude well or predict the behavior. “Are you going to contribute to the United Fund this year?” is notorious in that over twice the percentage of respondents respond positively than actually contribute. If nuclear images are overwhelmingly negative (Slovic et al., 1991), there might be a socially desirable element in responding negatively to questions related to nuclear facilities (Noelle-Neumann, 1993) regardless of actual opinions.

Even if the attitude measures are accurate, holding negative images of nuclear facilities is not a good predictor of decisions, in part because the attitude is neither potent nor salient to most people. The studies of intentions ask questions now about behavior years in the future. In the absence of accidents, there is little reason to expect attitudes about the repository and transportation of spent nuclear fuel and high-level radioactive waste to ever be salient to most Nevadans and to most people considering vacationing in southern Nevada.

- **People do not seek to minimize risks, but to avoid significant threats to their health and safety.**

In assessing public perceptions of a high-level radioactive waste repository or other technologies often viewed as risky among the general public, there is a tendency to assume that everyone’s goal is to minimize risks. The reality is much more complex as people often prefer riskier activities (e.g., skiing, wilderness hiking) more than safer ones and more dangerous vacation destinations over safer places. There is a substantial literature explaining why some risks are acceptable and others unacceptable (e.g., Slovic, 1999). What matters in terms of motivating behavior are risk perceptions that oneself or one’s family might actually be harmed, not any desire for the lowest possible level of risk *per se.* What is important is not whether people think a repository would be riskier for Nevadans than the No-Action Alternative, but whether they think there is a meaningful likelihood that the repository or the transportation of spent nuclear fuel and high-level radioactive waste will harm them.

- **The theory of the “social amplification of risk,” as applied to the proposed repository and transportation of spent nuclear fuel and high-level radioactive waste, is that the consequences of an accident at Yucca Mountain or in transporting these materials would extend beyond the immediate victims. The theory is that an accident would result in people thinking about possible risks associated with the repository and transportation, and taking actions intended to reduce risks.**

Slovic et al. (1991) summarizes:

> “The informativeness or signal potential of a mishap, and thus its potential social impact, appears to be systematically related to the perceived characteristics of the hazard. An accident that takes many lives may produce relatively little social disturbance (beyond that caused to the victims’ families and friends) if it occurs as part of a familiar and well-understood system (e.g., a train wreck). However, a small accident in an unfamiliar system (or one perceived as poorly understood), such as a nuclear waste repository or a recombinant DNA laboratory, may have immense social consequences if it is perceived as a harbinger of future and possibly catastrophic mishaps” (1991, 685).

According to the theorists (Kasperson et al., 1988) who developed the theory of the “social amplification of risk,” the mere existence of a facility such as a repository will neither raise fears nor influence decisions. An accident is needed to generate the process that amplifies risk perceptions and related behavior.

The theory of the "social amplification of risk" is only relevant to assessing the link between attitudes and behavior if there were to be an accident at Yucca Mountain or in transporting spent nuclear fuel and high-level radioactive waste. The theory provides a plausible explanation of how an accident could make attitudes salient and lead to behavior consistent with those attitudes.

- **"Stigma" theory, as applied to the proposed repository and transportation of spent nuclear fuel and high-level radioactive waste, is that the consequences of an accident at Yucca Mountain or in transporting these materials would lead to a widely-held negative stereotype of southern Nevada so that (1) many businesses and people would decide to locate elsewhere and (2) many erstwhile and potential vacationers to southern Nevada would also go elsewhere.**

Stigma is "… a social construction that involves at least two fundamental components: (1) the recognition of difference based on some distinguishing characteristic, or 'mark'; and (2) a consequent devaluation..." (Dovidio, Major, and Crocker 2000, 3). Slovic et al. (1991) argue that places as well as people can be stigmatized. They suggest that images of nuclear facilities are so negative that an accident at Yucca Mountain or during transportation would trigger such a high level of concern that the entire region would become stigmatized. Slovic, Flynn, and Gregory write, "… the theory put forth to predict impacts conditions such impacts on the occurrence of *key events* that trigger negative images that, in turn, motivate individual, social, and institutional responses" (1994, 775).

Easterling reiterates:

> "Is the prospect of this facility more aversive than will be true of the actual facility? The answer will depend on whether people grow accustomed to the repository (i.e., become desensitized to the current connotations) once the facility becomes a reality. This, in turn, will likely hinge on the track record of the repository once it becomes operational; an accident-prone facility would reinforce the pre-existing attributions, whereas an uneventful track record may defuse the fears that are currently associated with a repository" (Easterling 2001, 142).

Stigma theory is a variant of the "social amplification of risk." Both are relevant to assessing the link between attitudes and behavior only if there were to be an accident at Yucca Mountain or in transporting spent nuclear fuel and high-level radioactive waste. Stigma provides a plausible explanation of how an accident could make attitudes salient and lead to behavior consistent with those attitudes. As Slovic and Flynn write, "…our aim (with stigma research) was to demonstrate a *mechanism,* grounded in theory and data, by which substantial impacts could occur—just as they have occurred with some hazardous waste sites and some other events—such as the Tylenol scare" (1991, 701). If there are no significant accidents in the operation of the repository and with transportation, there is no reason for stigma to happen.

5.0 Linking Risk Perceptions and Behavior to Socioeconomic Impacts

This section links the perception and behavior research to socioeconomic impacts.

- **Perceptions about a repository and transportation of spent nuclear fuel and high-level radioactive waste are unlikely to engender behavior that will harm the Nevadan economy.**

The mainstay of the economy of southern Nevada involves tourism and other services in the Las Vegas area. Absent serious accidents, there is little reason to expect the repository program to discourage businesses and persons considering moving to southern Nevada, or vacationers.

Even if there is a serious accident, stigmatization might not happen. Hershey Park, a large amusement park 11 miles from Three Mile Island, continues to set attendance records. The area directly downwind of Three Mile Island has had the most economic growth of any Pennsylvania region since the 1979 accident.

The mere presence of radioactive waste does not necessarily discourage tourism. Disneyland is 35 miles from San Onofre, where at-reactor storage of spent nuclear fuel takes place. In 2000, 38 million tourists visited New York City, which is less than 90 miles from a nuclear power plant with at-reactor storage.

- **The eco-tourism segment of the southern Nevada economy appears most vulnerable to adverse socioeconomic impacts from perceptions.**

Eco-tourism is travel and visitation to relatively undisturbed natural areas in order to enjoy and appreciate nature in a manner that promotes conservation. Jenkins-Smith (2001) presents data that suggests that the people most likely not to visit Nevada because of the repository have values similar to eco-tourists. Absent accidents, therefore, the segment of the southern Nevada economy most vulnerable to perception impacts might be the eco-tourism industry. Eco-tourism at present does not appear to be a large component of the southern Nevada economy.

- **Both stigma and the social amplification of risk require a trigger (e.g., a major accident) to bring about behavioral changes and adverse socioeconomic impacts.**

If there are no serious accidents, there will be no stigma and no social amplification of risk.

- **The repository would not reduce property values.**

The closest analogies we have to the proposed repository are low-level waste facilities, Federal nuclear reservations (e.g., Hanford), the Waste Isolation Pilot Project, and nuclear power plants. There is little evidence of negative impacts on property values in the vicinity of nuclear facilities, even Three Mile Island, site of America's most publicized nuclear accident (Gamble, Downing, and Sauerlender, 1980; Gamble and Downing, 1982; Nelson 1981). Impacts that have occurred (e.g., the area of the Fernald weapons plant in Ohio) are linked to contamination, not the mere presence of nuclear facilities. Hunsperger (2001) and Feiertag (1992) suggest that contaminated Federal facilities have impacts similar to those of Superfund sites.

- **Perceptions might temporarily reduce property values along urban transportation corridors by approximately 3 percent, although other research shows that impacts might be negligible or nonexistent.**

The UER (2001) and Gawande and Jenkins-Smith (2001) studies suggest that, at least temporarily, residential property values in transportation corridors in urban areas may decline approximately 3 percent. Data from other transportation experiences (e.g., transuranic waste to WIPP) suggest that impacts on property values might be negligible or nonexistent.

6.0 Conclusions

There is a consensus among social scientists that a quantitative assessment of the potential impacts from risk perceptions of the proposed repository and the transportation of spent nuclear fuel and high-level radioactive waste is impossible at this time and probably unlikely even after extensive additional research. The implication is not that impacts would probably be large, but simply difficult to quantify. As the NWTRB noted in 1995, social scientists do not know enough to identify what would be the level of concern during the operation of a repository, if it does open. Similarly, we cannot specify the links between those attitudes and individual decisions that would have socioeconomic impacts. Based upon what we do know from surveys and from analogues, we can assess qualitatively what outcomes seem most likely.

6.1 Effects from Perceptions of the Proposed Repository

Social scientists are loath to write that something in the future is impossible. Thinking like science fiction authors, social scientists can conjure sequences of extremely unlikely events that, taken together, can result in tragic consequences.

The answers to questions about socioeconomic impacts from perceptions vary by how the question is phrased. If the question asks if significant adverse socioeconomic impacts are possible if the repository were to open, the answer of course is affirmative, even without science fiction. The more useful question asks whether there is a reasonable likelihood that perceptions about an operating repository are likely to engender significant adverse socioeconomic impacts. In the absence of a large accident at the repository or a continuing series of smaller accidents, there is little reason to expect significant adverse effects:

- Although, when asked, many people report that they think of nuclear things as dangerous, these attitudes are usually not salient in people's lives and therefore do not influence personal decisions. People do not consider that spent nuclear fuel is stored at San Onofre when they decide whether to visit Disneyland.

- Yucca Mountain is not in Las Vegas, but a significant distance away in the desert.

- Studies show few indications of adverse socioeconomic effects (and many positive socioeconomic effects) in places that currently safely store or dispose of radioactive waste. As New Mexico has not become stigmatized as the "transuranic nuclear waste dump state," there is little reason to expect that Nevada would be stigmatized.

- People who choose to vacation in Las Vegas are less likely to be concerned about the repository than people who choose to vacation elsewhere. Opening the repository, if there is any impact, would be likely to re-enforce the preferences of people who do not intend to visit Las Vegas with or without an operating repository 90 miles away. People who do like to visit Las Vegas would likely pay little attention.

- If the repository would be such a powerful disincentive to investors, businesses considering relocating to southern Nevada, and retirees and others considering relocating in the area, some effects of those perceptions should already be apparent. It is widely known that Congress has ordered DOE to characterize Yucca Mountain for consideration for a repository and that key program documents suggest that the site might be acceptable. If a repository were such a powerful disincentive, prudent investors, facing a possible opening of a repository, would not be investing in southern Nevada. Similarly, we would see a decline in population in southern Nevada as businesses and people decide to settle elsewhere in anticipation of future risks and stigma. There is no evidence of this behavior.

The assessment that substantial adverse socioeconomic impacts from perceptions of the repository are quite unlikely assumes that operations at the facility will not have either a major accident (e.g., an explosion with a significant release of ionizing radiation bringing about exposures downwind, some cases of radiation poisoning, and deaths) or periodic smaller accidents (e.g., damaged canisters with some releases of ionizing radiation). These events would most likely raise fears about a repository, make a repository salient to people in southern Nevada, result in some social amplification of risk, and perhaps even stigmatize the region. Adverse socioeconomic effects from perceptions of an accident-prone repository might be substantial even with the repository 90 miles away. Without nuclear accidents at Yucca Mountain, these effects are quite unlikely.

6.2 Effects from Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste

As with socioeconomic impacts from perceptions about a repository, the answers to questions about potential impacts from the transportation of spent nuclear fuel and high-level radioactive waste vary with how the question is posed. Are significant adverse impacts possible? Large impacts are possible if there are accidents with releases of ionizing radiation during the transportation of spent nuclear fuel and high-level radioactive waste. The social amplification and risk and stigma might become quite relevant after an accident that exposes neighborhoods to ionizing radiation.

A different question is whether there is a reasonable likelihood that perceptions about transporting spent nuclear fuel and high-level radioactive waste are likely to engender significant adverse socioeconomic impacts. Absent accidents, there is no reason to expect impacts for property owners in areas beyond the transportation corridors. Even absent accidents, however, some studies (UER 2001; Gawande and Jenkins-Smith 2001) report that, at least temporarily, a decline in residential property values of approximately 3 percent might be expected in transportation corridors in urban areas. Data from other transportation experiences (e.g., transuranic waste to WIPP) suggest that impacts on property values might be negligible or nonexistent. More research on whether property values have fluctuated, and for how long, with the transportation of radioactive materials would be beneficial, although the research would not allow analysts to know with certainty whether there would be any impacts from perceptions of shipments of spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository.

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Appendix O

U.S. Fish and Wildlife Service
Biological Opinion

United States Department of the Interior

FISH AND WILDLIFE SERVICE
NEVADA FISH AND WILDLIFE OFFICE
1340 FINANCIAL BOULEVARD, SUITE 234
RENO, NEVADA 89502

August 28, 2001
File No. 1-5-00-F-518

Mr. Stephan Brocoum, Assistant Manager
Office of Licensing and Regulatory Compliance
U.S. Department of Energy
Post Office Box 30307
North Las Vegas, Nevada 89036-0307

Dear Mr. Brocoum:

Subject: Final Biological Opinion for the Effects of Construction, Operation and Monitoring, and Closure of a Geologic Repository at Yucca Mountain, Nye County, Nevada

This document transmits the U.S. Fish and Wildlife Service's (Service) final biological opinion based on our review of the proposed construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain, Nye County, Nevada, and its effects on the federally-threatened Mojave desert tortoise (*Gopherus agassizii*) in accordance with section 7 of the Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531 *et seq*.). Your April 24, 2000, request for formal consultation was received on May 1, 2000.

This biological opinion is based on information provided in the April 2000 biological assessment (Department of Energy [DOE] 2000a); DOE correspondence to the Field Supervisor, Nevada Fish and Wildlife Office dated April 24, 2000, September 22, 2000, October 12, 2000, February 15, 2001 (DOE 2001a), April 5, 2001 (DOE 2001b), June 12, 2001, and August 22, 2001; DOE's August 2000 correspondence with the National Marine Fisheries Service; draft environmental impact statement (DEIS) dated July 1999 (DOE 1999); biological opinions for site characterization studies at Yucca Mountain (File Nos. 1-5-90-F-6 and 1-5-96-F-307R); meetings between a DOE representative and Service staff on September 11, 1998, and March 18, 1999; conversations with DOE and representative staff; and our files. A complete administrative record of this consultation is on file in the Southern Nevada Field Office.

Consultation History

On February 9, 1990, the Service issued a non-jeopardy biological opinion to DOE for site characterization studies at Yucca Mountain (File No. 1-5-90-F-6). In the biological opinion, the

Service required DOE to continue their 1989 desert tortoise monitoring program (DOE 1989) which included the following objectives: (1) Determine relative abundance and distribution of desert tortoises on the project site, (2) implement a long-term program to monitor the relative abundance of tortoises at Yucca Mountain and the effects of site characterization activities on the species, (3) monitor the presence of any disease in desert tortoises, (4) study the movements and habitat use of desert tortoises and develop a model of desert tortoise habitat, (5) conduct field studies to determine the efficacy of relocating tortoises to new areas, (6) conduct field studies to determine the efficacy of fences and underpasses along roads to prevent vehicles from killing tortoises, and (7) monitor populations of ravens and other desert tortoise predators. These studies were conducted by DOE and their contractors at the estimated cost of $4 million (DOE 2001b). A list of reports, publications, and abstracts provided by DOE in their April 5, 2001, letter (DOE 2001b) identifies the reference documents for these studies.

In the 1990 biological opinion, the Service determined that approximately 15 desert tortoises might be affected within the 450-acre project area. Subsequently, it became apparent that the estimated number of tortoises encountered at the project site was higher than anticipated in the previous biological opinion. On February 22, 1995, the Service requested that DOE request reinitiation of consultation for site characterization studies. By Service letter to DOE dated September 18, 1996, following the August 7, 1996, meeting among DOE and Service staff, it was mutually agreed between DOE and the Service that the continuation of project activities at Yucca Mountain would not result in DOE expenditures, studies, or monitoring in excess of those stipulated in the 1990 biological opinion (Service 1996). The Service reinitiated formal consultation on December 9, 1996, and issued a new biological opinion to DOE on July 23, 1997 (File No. 1-5-96-F-307R). This reinitiated biological opinion shall remain in effect until site characterization studies are completed.

On December 17, 1998, and February 4, 2000, DOE requested an updated species list for the project area, which was provided by the Service on January 21, 1999, (File No. 1-5-99-SP-059) and February 25, 2000 (File No. 1-5-00-SP-440), respectively.

In your April 24, 2000, letter, DOE determined that transportation of nuclear materials will involve routine transportation methods and routes and will insignificantly increase traffic volumes. Thus, DOE determined that transportation of nuclear materials from the 77 sites identified in the biological assessment will result in "no effect" to federally listed species.

DOE evaluated the potential effects to 47 federally-listed species from transportation of nuclear materials from various sites across the nation to Yucca Mountain which may involve the use of barges in the marine environment (DOE 2000b). In their DEIS, DOE showed that the likelihood of an accident involving spent nuclear fuel on a marine barge is extremely small, and the further likelihood of an accident resulting in release of radioactivity is even smaller. Because the locations of accidents would be random, the likelihood that threatened and endangered species would be involved is reduced further. Based on these analyses, DOE concluded that the likelihood of these improbabilities resulting in an accident that may affect listed species or critical habitat, is so small that it can be considered discountable. Subsequently, on August 17, 2000, DOE determined that only the desert tortoise may be affected by the subject project (DOE 2000b).

The Service initiated formal consultation upon receipt of your request on May 1, 2000. On September 13, 2000, the Service requested a 60-day extension of the consultation period. DOE concurred with the request by letter dated September 22, 2000. Subsequently, DOE requested that the consultation period be extended to approximately November 15, 2000, to allow DOE time to refine the level of disturbance anticipated as a result of the proposed action. On February 22, 2001, the Service received DOE's modifications to the previous project description that would result in an additional 1,100 acres of disturbance of desert tortoise habitat (DOE 2001b). In response, the Service requested additional information on February 23, 2001, on the potential effects to desert tortoise that may result from the proposed modification. DOE provided that information by correspondence dated April 5, 2001 (DOE 2001a).

On May 8, 2001, the Service issued a draft biological opinion to DOE on the subject project and requested comments on the draft by May 18, 2001. On May 23, 2001, DOE requested that the deadline for comments be extended to June 15, 2001, and the opportunity to review the draft biological opinion before it is finalized. The Service concurred and received DOE's comments on the draft biological opinion on June 15, 2001. A second draft biological opinion was issued to DOE on July 26, 2001. On August 22, 2001, DOE submitted a letter to the Service stating that DOE has no further comments on the draft opinion and requested a final biological opinion on the subject project.

Description of the Proposed Action

The DOE proposes to construct, operate and monitor, and eventually close a geological repository on the Nevada Test Site (NTS) and surrounding lands at Yucca Mountain, Nevada, for the disposal of approximately 77,000 tons of commercial and DOE owned nuclear waste. The project site is located in a remote area of southern Nye County, Nevada, approximately 93 miles northwest of Las Vegas, Nevada Figure 1). Construction, operation and monitoring, and closure of the repository will require the active use of up to 1,643 acres of land, in addition to areas used during site characterization studies, and up to 430 acre-feet of groundwater per year. The nuclear waste would consist of spent nuclear fuel and high-level nuclear waste (HLW) presently stored at 72 commercial nuclear power generating facilities and 5 DOE facilities. These materials would be transported to a repository at Yucca Mountain using a combination of methods including barges, legal-weight trucks, heavy haul trucks, and rail. *Legal-weight trucks* have a gross vehicle weight of less than 40 tons which is the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. *Heavy-haul trucks* are overweight, over-dimension vehicles that must have permits from state highway authorities to use public highways.

The project includes the repository site (Figure 2), potential corridors within Nevada and an approximately 6-mile-long segment in California where a branch rail line may be constructed (Figure 3), potential intermodal transfer station sites (Figure 4), and potential heavy-haul routes, including areas where necessary highway upgrades may occur (Figure 5). The specific method and route of transport has not been determined at this time, therefore, the potential effects to desert tortoise that may result from transportation of materials, including construction of transportation infrastructure, will be evaluated in future consultations under section 7 of the Act. Future Federal actions will be required for proposed transportation of materials associated with the subject project including issuance of right-of-way grants and/or acquisition and expenditure of Federal highway funds. The Service anticipates that DOE would comply with the terms and conditions of biological opinions issued to other Federal agencies, as appropriate, for future transportation projects associated with the repository.

Repository Construction

DOE proposes to construct and use above- and below-ground facilities. The construction phase would likely include new construction, modification, and maintenance of infrastructure (e.g., electrical and water lines); construction of roads, buildings, parking areas, sanitary waste lines and drain fields; borrow pits; evaporation ponds; topsoil and rock storage areas; storm water retention basins; a solid waste landfill; a surface aging area; ventilation shafts; a solar power system; and underground tunnels. These facilities would be required to support receipt and repackaging of spent nuclear fuel (SNF) and HLW into waste packages, placing waste packages underground, maintaining a capability to retrieve the waste packages if needed, monitoring, and closing the repository. Most facilities developed to process SNF and HLW, and support construction of the below-ground facilities would be located in the North Portal Operations Area, the South Portal Development Operations Area, the Emplacement Ventilation Shaft Area, and the Development Ventilation Shaft Area (Figure 2).

Excavated rock (muck) from the repository would be transported through the South Portal and moved to a muck storage area on or near Midway Valley or Jackass Flats using trucks or an overland conveyor system. Site water would come from NTS J-12, J-13, and C wells, south and southeast of the North Portal Operations Area. The wells and distribution piping to the repository already exist, however additional infrastructure may be required and routine maintenance would be performed. Sanitary sewage would be routed to septic tank/leach field wastewater-treatment systems which would be established near the facilities using them.

DOE is considering constructing a 3-megawatt solar power generating facility to meet the energy requirements of the proposed repository. The solar facility would likely be located in Midway Valley, 1.2 to 2.5 miles east or northeast of the North Portal Operations Area (Figure 2). Approximately 25 acres would be disturbed during construction of the facility and access road. A power transmission line connecting the facility to the North Portal would likely be constructed within an existing, previously disturbed right-of-way. The solar facility would be built in phases of 500 kilowatts per year, starting in 2005, and would likely be connected to the site power distribution system.

It is possible that regulatory changes would allow up to 11,000 tons of SNF and HLW to be received before the start of underground emplacement of waste packages. In this case, a concrete pad, associated facilities, and infrastructure would be constructed in or near Midway Valley for temporary holding prior to being placed underground.

Construction of the repository facilities could begin only after receipt of construction authorization from the Nuclear Regulatory Commission. DOE estimates that construction may begin in 2005. The repository surface facilities, main drifts, ventilation system, and initial emplacement drifts would be built in approximately 5 years, from 2005 to 2010. Beginning in 2010, the older and cooler commercial spent nuclear fuel could be loaded into waste packages and emplaced into the repository. Construction of emplacement drifts would continue until approximately 2032.

Repository Operation and Monitoring

Above-ground facilities would be used to receive, prepare, and repackage SNF and HLW for placement into the below ground repository. Unloading, handling, and repackaging of material would occur in a radiologically-controlled area, and would be controlled remotely. Secondary wastes generated by repository operations would include low-level radioactive, hazardous, sanitary, and industrial solid wastes. Although unlikely, small amounts of low-level mixed radioactive waste could be generated. Some wastes could be processed and/or packaged onsite. All low-level and low-level mixed waste would be shipped offsite for disposal. Hazardous waste would be packaged and shipped offsite for treatment and disposal. Industrial waste would be disposed of either offsite or in a landfill developed in the Yucca Mountain area. Sanitary liquid waste would be processed through the sanitary waste water system. Ventilation exhaust from the repository would be a mixture of hot air (approximately 310^0 F) from the closed emplacement drifts, and cooler air from the open drifts where waste packages would be emplaced.

Closure/Post Closure

Closure of the repository and facilities may include decommissioning buildings and equipment; removal of equipment and other materials from the site; backfilling of the main drifts, ramps, shafts and connecting openings; and final site reclamation. Reclamation may include recontouring disturbed areas, surface backfill, soil buildup and reconditioning, site vegetation, site water course configuration, and erosion control.

Heat generated from the emplaced SNF and HLW is expected to warm the surrounding rock and soil above the repository over 750 to 2,500 acres. Increases in soil temperature are expected to begin about 200 years after waste package emplacement in the repository, and to reach maximum levels in about 700 years. DOE estimates that the temperature increase would be approximately 0.7^0 F for wet soil and 5^0 F for dry soil. The repository is designed with the capability for closure as early as 50 years, or as late as 300 years, after the start of emplacement. The period to accomplish closure would range from 6 to 15 years.

Transportation Options

The national routes taken to transport SNF and HLW to the repository would occur on the existing national transportation infrastructure of waterways, highways, and railroads. The exceptions to this are the potential construction of a branch rail line in Nevada and approximately 6 miles in California (Jean rail corridor option), potential construction of an intermodal transfer station in Nevada for the transfer of rail shipments to heavy-haul trucks, and potential modification of existing highways within Nevada to allow travel of heavy-haul trucks. For transport within Nevada, three options were considered by DOE which include (1) mostly legal-weight trucks, (2) mostly heavy-haul trucks, and (3) mostly rail.

If the rail transport option within Nevada is chosen to transport SNF and HLW to the repository, construction of a branch rail system would be required to connect the mainline rail with Yucca Mountain. If heavy-haul trucks are used, an intermodal transfer facility would be constructed where shipments would be transferred from rail cars to heavy-haul trucks for final shipment to the repository at Yucca Mountain. Five branch rail line corridors, five potential heavy-haul routes, and three general sites for potential intermodal transfer facilities have been identified within Nevada (Figure 4). Two of the three transfer facilities occur within the range of the desert tortoise but outside any areas designated for recovery of the species. The use of legal-weight truck transportation would not require construction. Legal-weight trucks would enter Nevada on

Interstate 15 from either the north or south, travel through the Las Vegas area using beltways currently under construction, and travel north on a U.S. Highway to Yucca Mountain.

Rail branch or intermodal transfer facility construction, or highway modifications will require Federal authorization or funding and, therefore, will be subject to future consultation under section 7 of the Act with the appropriate Federal agency such as the Bureau of Land Management (BLM) or the Federal Highway Administration. At that time, potential effects to desert tortoise will be identified and evaluated under the appropriate consultation procedures.

As minimization measures, DOE (2000a, 2001b) proposes the following measures to minimize effects to desert tortoises from the proposed action, which include the following:

1. All DOE and contractor personnel working at Yucca Mountain and on transportation construction projects within the range of the desert tortoise will complete a desert tortoise education program. This program will explain the legal status of desert tortoises, the definition of "take," and penalties for violations of Federal and State laws regarding tortoises. The program will include information on the life history of the desert tortoise and general tortoise activity patterns, what to do if a tortoise is sighted (including how to safely move tortoises off roads), and an explanation of measures designed to protect tortoises (e.g., speed limits, prohibition of off-road driving, etc.).

2. Clearance surveys will be conducted prior to clearing of vegetation at previously undisturbed sites if new disturbances are larger than 5 acres. Most areas where disturbances will take place have a low abundance of tortoises and the likelihood of finding tortoises in sites less than 5 acres in size is small. In addition, most smaller disturbances would be distant from larger disturbances, be short in duration, and would involve minimal equipment.

3. A tortoise biologist or environmental monitor will be available during construction activities to help ensure that desert tortoises are not inadvertently harmed. Project activities that may endanger a tortoise will cease if a tortoise is found on a project site. Project activities will resume only after a biologist or environmental monitor ensures that the tortoise is not in danger or after the tortoise has moved to a safe area.

4. All vehicles will be driven at speeds within the posted speed limits on existing roads, and will not exceed 25 miles per hour on unposted roads. Vehicles will not be driven off existing roads in non-emergency situations unless authorized by DOE. During the tortoise activity season (February 16 through November 14) the proposed vehicle path will be cleared of tortoises immediately prior to off-road travel. During the tortoise

inactive season, the proposed vehicle path will be cleared of tortoises within 7 days prior to off-road travel.

5. A litter-control program will be implemented that will include the use of covered trash receptacles, disposal of edible trash in trash receptacles following the end of each work day, and disposal of trash in a designated sanitary landfill. Any material placed in a sanitary landfill operated by the Yucca Mountain project will be covered often enough to prevent scavengers and predators from feeding there.

6. All non-linear habitat disturbances larger than 2.5 acres at Yucca Mountain which have had vegetation removed but no longer being used will be revegetated in accordance with the *Reclamation Implementation Plan* (DOE 1995) and the *Reclamation Standards and Monitoring Plan* (RSMP) (DOE 1998). These plans may include specifications for contouring, relieving soil compaction, treating and/or spreading topsoil, seeding, and using transplants.

Status of the Species- Rangewide

The desert tortoise is a large, herbivorous reptile found in portions of California, Arizona, Nevada, and Utah. It also occurs in Sonora and Sinaloa, Mexico. The Mojave population of the desert tortoise includes those animals living north and west of the Colorado River in the Mojave Desert of California, Nevada, Arizona, southwestern Utah, and in the Colorado Desert in California. Desert tortoises reach 8 to 15 inches in carapace length. Adults have a domed carapace and relatively flat, unhinged plastron. Shell color is brownish, with yellow to tan scute centers. The forelimbs are flattened and adapted for digging and burrowing. Optimal habitat has been characterized as creosote bush scrub in which precipitation ranges from 2 to 8 inches, where a diversity of perennial plants is relatively high, and production of ephemerals is high (Luckenbach 1982, Turner 1982, Turner and Brown 1982). Soils must be friable enough for digging of burrows, but firm enough so that burrows do not collapse. Desert tortoises occur from below sea level to an elevation of 7,300 feet, but the most favorable habitat occurs at elevations of approximately 1,000 to 3,000 feet (Luckenbach 1982).

Desert tortoises are most active during the spring and early summer when annual plants are most common. Additional activity occurs during warmer fall months and occasionally after summer rain storms. Desert tortoises spend the remainder of the year in burrows, escaping the extreme conditions of the desert. The size of desert tortoise home ranges vary with respect to location and year. Females have long-term home ranges that are approximately half that of the average male, which range from 25 to 200 acres (Berry 1986). Over its lifetime, each desert tortoise may require more than 1.5 square miles of habitat and make forays of more than 7 miles at a time (Berry 1986). In drought years, the ability of tortoises to drink while surface water is available following rains may be crucial for tortoise survival. During droughts, tortoises forage over larger areas, increasing the likelihood of encounters with sources of injury or mortality including humans and other predators. Desert tortoises possess a combination of life history and reproductive characteristics which affect the ability of populations to survive external threats. Tortoises may require 20 years to reach sexual maturity (Turner et al. 1984; Bury 1987).

The desert tortoise is most commonly found within the desert scrub vegetation type, primarily in creosote bush scrub. In addition, it is found in succulent scrub, cheesebush scrub, blackbrush scrub, hopsage scrub, shadscale scrub, microphyll woodland, Mojave saltbush-allscale scrub, and scrub-steppe vegetation types of the desert and semidesert grassland complex (Service 1994). Within these vegetation types, desert tortoises potentially can survive and reproduce where their basic habitat requirements are met. These requirements include a sufficient amount and quality of forage species; shelter sites for protection from predators and environmental extremes; suitable substrates for burrowing, nesting, and overwintering; various plants for shelter; and adequate area for movement, dispersal, and gene flow. Throughout most of the Mojave Region, tortoises occur most commonly on gently sloping terrain with soils ranging from sand to sandy-gravel and with scattered shrubs, and where there is abundant inter-shrub space for growth of herbaceous plants. Throughout their range, however, tortoises can be found in steeper, rockier areas. Further information on the range, biology, and ecology of the desert tortoise can be found in Berry and Burge (1984); Burge (1978); Burge and Bradley (1976); Bury et al. (1994); Germano et al. 1994; Hovik and Hardenbrook (1989); Karl (1981, 1983a, 1983b); Luckenbach (1982); Service (1994); and Weinstein et al. (1987).

On August 4, 1989, the Service published an emergency rule listing the Mojave population of the desert tortoise as endangered (54 FR 42270). On April 2, 1990, the Service determined the Mojave population of the desert tortoise to be threatened (55 FR 12178). Reasons for the determination included loss of habitat from construction projects such as roads, housing and energy developments, and conversion of native habitat to agriculture. Grazing and off-highway vehicle (OHV) activity have degraded additional habitat. Also cited as threatening the desert tortoise's continuing existence were illegal collection by humans for pets or consumption, upper respiratory tract disease (URTD), predation on juvenile desert tortoises by common ravens (*Corvus corax*) and kit foxes (*Vulpes macrotis*), and collisions with vehicles on paved and unpaved roads. Fire is an increasingly important threat to desert tortoise habitat. Over 500,000 acres of desert lands burned in the Mojave Desert in the 1980s. Fires in Mojave desert scrub degrade or eliminate habitat for desert tortoises (Appendix D of Service 1994).

On February 8, 1994, the Service designated approximately 6.4 million acres of critical habitat for the Mojave population of the desert tortoise in portions of California, Nevada, Arizona, and Utah (59 FR 5820), which became effective on March 10, 1994. Critical habitat is designated by the Service to identify the key biological and physical needs of the species and key areas for recovery, and focuses conservation actions on those areas. Critical habitat is composed of specific geographic areas that contain the primary constituent elements of critical habitat, consisting of the biological and physical attributes essential to the species' conservation within those areas, such as space, food, water, nutrition, cover, shelter, reproductive sites, and special habitats. The specific primary constituent elements of desert tortoise critical habitat are: Sufficient space to support viable populations within each of the six recovery units (RUs), and to provide for movement, dispersal, and gene flow; sufficient quality and quantity of forage species and the proper soil conditions to provide for the growth of these species; suitable substrates for burrowing, nesting, and overwintering; burrows, caliche caves, and other shelter sites; sufficient vegetation for shelter from temperature extremes and predators; and habitat protected from disturbance and human-caused mortality.

Approximately 1.2 million acres were designated as critical habitat in Nevada. Critical habitat units (CHUs) were based on recommendations for Desert Wildlife Management Areas (DWMAs) outlined in the *Draft Recovery Plan for the Desert Tortoise (Mojave Population)* (Service 1993). These DWMAs are also identified as "desert tortoise areas of critical environmental concern (ACECs)" by the BLM. Because the CHU boundaries were drawn to optimize reserve design, the CHU may contain both "suitable" and "unsuitable" habitat. Suitable habitat can be generally defined as areas that provide the primary constituent elements. The Yucca Mountain project area does not occur within desert tortoise critical habitat.

On June 28, 1994, the Service approved the final Desert Tortoise Recovery Plan (Service 1994). The Desert Tortoise Recovery Plan divides the range of the desert tortoise into 6 RUs and recommends establishment of 14 DWMAs throughout the RUs. Within each DWMA, the Desert Tortoise Recovery Plan recommends implementation of reserve-level protection of desert tortoise populations and habitat, while maintaining and protecting other sensitive species and ecosystem functions. The design of DWMAs should follow accepted concepts of reserve design. As part of the actions needed to accomplish recovery, the Desert Tortoise Recovery Plan recommends that land management within all DWMAs should restrict human activities that negatively impact desert tortoises (Service 1994). DWMAs have been designated by the BLM through development or modification of their land use plans in Nevada, Arizona, and Utah. Land-use planning activities are underway in California to designate DWMAs/ACECs. The regulation of activities within critical habitat through section 7 consultation is based on recommendations in the Desert Tortoise Recovery Plan. DWMAs/ACECs have been designated in Utah, Arizona, and Nevada. Similar designations are in progress in California for the Western

Mojave RU, and Northern and Eastern Colorado RUs. Yucca Mountain occurs within the Northeastern Mojave RU near the boundary with the Eastern Mojave RU, but not within a proposed DWMA.

The Northeastern Mojave RU occurs primarily in Nevada, but it also extends into California along the Ivanpah Valley and into extreme southwestern Utah and northwestern Arizona. Vegetation within this unit is characterized by creosote bush scrub, big galleta-scrub steppe, desert needlegrass scrub-steppe, and blackbrush scrub (in higher elevations). Topography is varied, with flats, valleys, alluvial fans, washes, and rocky slopes. Much of the northern portion of the RU is characterized as basin and range, with elevations from 2,500 to 12,000 feet. Desert tortoises typically eat summer and winter annuals, cacti, and perennial grasses. Desert tortoises in this RU, the northern portion of which represents the northernmost distribution of the species, are typically found in low densities (approximately 10 to 20 adults per square mile).

Recovery of the desert tortoise may occur at the recovery unit level which allows populations within each of the six recovery units to be recovered and delisted individually. Similarly, the jeopardy and adverse modification standards may be applied within or across recovery units. Thus, proposals to implement the Desert Tortoise Recovery Plan in portions of a recovery unit cannot be evaluated with regard to jeopardy or adverse modification in a section 7 consultation without an understanding of proposed or existing management prescriptions occurring elsewhere in the recovery unit.

Long-term monitoring of desert tortoise populations is a high priority recovery task as identified in the Desert Tortoise Recovery Plan. From 1995 to 1998, pilot field studies and workshops were conducted to develop a monitoring program for desert tortoise. In 1998, the Desert Tortoise Management Oversight Group chose line distance sampling as the appropriate method to determine rangewide desert tortoise population densities and trends. Monitoring of populations using this method is underway across the range of the desert tortoise and baseline population data will be forthcoming within the next year. Successful rangewide monitoring will enable managers to evaluate the overall effectiveness of recovery actions and population responses to these actions, thus guiding recovery of the Mojave desert tortoise.

Environmental Baseline

The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation process.

Yucca Mountain is located in Nye County, Nevada, approximately 93 miles northwest of Las Vegas and crosses the jurisdictional boundaries of DOE, the U.S. Air Force (USAF), and BLM. The areas managed by the DOE and USAF have been reserved for use by government agencies in support of national security needs, and have been restricted from public access and grazing since the early 1950s (DOE 1997).

Yucca Mountain occurs on the northern edge of the Mojave Desert along an ecotone between the Great Basin and Mojave deserts with a maximum elevation of 4,950 feet. The area is characterized by three vegetation associations (DOE 1997). An association dominated by shrubs including primarily creosotebush (*Larrea tridentata*), white bursage (*Ambrosia dumosa*), spiny hopsage (*Grayia spinosa*), and Mormon tea (*Ephedra nevadensis*) is found on alluvial slopes in the Mojave Desert zone below approximately 4,265 feet. Mormon tea, spiny hopsage, and wolfberry (*Lycium andersonii*) dominate the vegetation association in the transition zone on alluvial slopes above approximately 4,265 feet and on the upper slopes of Yucca Mountain. The third vegetation association occurs on upper alluvial slopes and relatively level ridges, between approximately 3,800 and 4,950 feet is dominated by blackbrush (*Coleogyne ramosissima*) (DOE 1997).

Status of the Species in the Action Area

Karl (1989) conducted desert tortoise surveys in the Yucca Mountain area between September 17 and 23, 1989. A total of 23 strip transects were walked to assess distribution, habitat associations, and relative abundances of tortoise. According to the surveys, tortoises preferred large alluvial fans in the eastern portion of the area. Karl estimated that the density of desert tortoises ranged from 10 to 50 tortoises per square mile. The steep ridge/drainage mosaic in the western portion of Yucca Mountain had the least sign, and was considered poor habitat. Existing disturbance as a result of DOE activities in the Yucca Mountain area consisted of approximately 641 acres as a result of drill holes, trenches and test pits, seismic surveys, monitoring stations, bladed use facilities, and roads and corridors. The area with greatest disturbance was located along Drill Hole Wash Road. Additional disturbance was observed as a result of trespass cattle grazing.

Biologists with EG&G/Energy Measurements (EG&G/EM) (1991) conducted 341 transects from 1981 through 1984 in the Yucca Mountain area, covering approximately 322 linear miles. During the transects, 0.17 tortoise sign was found per mile of transect walked, including nine tortoises. Sign was found between 3,280 and 5,250 feet in elevation. Between 1987 and 1990, EG&G/EM biologists conducted additional transects during tortoise population and impact monitoring studies on the NTS. During these surveys, 54 desert tortoises were found at Yucca Mountain during 1989-1990 (EG&G/EM 1991). Based on transects and studies conducted from

1981 through 1995, DOE concluded that desert tortoises are widespread throughout Yucca Mountain and occur in all three of the common vegetation associations at Yucca Mountain (DOE 1997). Observational data recorded in the Yucca Mountain area during field work conducted from 1989 through 1995 suggest that desert tortoise densities are within the range of 10 to 50 per square mile presented by Karl (1989).

Between July 1991 and September 1995, biologists under contract to DOE monitored 95 radio telemetered tortoises to determine their location and behavior. Data collected during this monitoring program indicated that tortoises were inactive November 15 through February 15. During this period, tortoises were in burrows during 4,102 of 4,119 observations (Rautenstrauch et al. 1997). Because Yucca Mountain is located at higher elevations than average (approximately 3,200 to 4,950 feet) and at the northernmost distribution of the range of desert tortoise, these data may be different from inactive periods in other parts of the range of the desert tortoise. Based on the information above, the Service determined the tortoise active season at Yucca Mountain to be November 15 through February 15.

<u>Major Activities Authorized Under Sections 7 and 10(a)(1)(A) of the Act in the Action Area</u>

On February 9, 1990, the Service issued a non-jeopardy biological opinion to DOE for site characterization studies at Yucca Mountain (File No. 1-5-90-F-6) which was reinitiated on December 9, 1996, and superceded by a new biological opinion on July 23, 1997 (File No. 1-5-96-F-307R). A total of 375 acres of desert tortoise habitat has been disturbed of the 450 acres that DOE anticipated to disturb as a result of site characterization activities (DOE 2000a). During the site characterization studies, a total of five (5) desert tortoises were killed or injured, all of which were within the incidental for the 450-acre project area. Four (4) of these mortalities were the result of tortoise encounters with project-related vehicles. The fifth tortoise was a hatchling which fell into a project trench and died. An additional 28 tortoises were moved out of harm's way. Two of the displaced tortoises subsequently died; however, it was not determined to be a direct result of project activities.

On August 26, 1994, the Service issued a recovery permit (PRT-781234) to EG&G/EM under section 10(a)(1)(A) of the Act to conduct studies on hatchling and adult desert tortoises in Nevada and California which was originally covered under EG&G's prior permit, PRT-683011. In their 1989 biological assessment for the site characterization studies at Yucca Mountain (DOE 1989), DOE proposed to continue a desert tortoise population monitoring program initiated in 1989 at Yucca Mountain, which was incorporated by reference in the terms and conditions of the 1990 biological opinion. These studies were conducted by EG&G/EM under PRT-781234 at

Yucca Mountain and elsewhere on the NTS. Between 1989 and 1995, a total of 555 tortoises were captured and marked; 308 of these tortoises were radio telemetered. Effective December 31, 1995, EG&G/EM ended their contract with DOE for the Yucca Mountain Project and the permit was not renewed.

Programmatic Biological Opinions Issued for Desert Tortoise in Nevada

File No. 1-5-91-F-112. On September 26, 1991, the Service issued a programmatic biological opinion to the BLM's Las Vegas District for implementation of their Management Framework Plan (MFP) within the boundaries of Clark County's incidental take permit in the Las Vegas Valley. As a result of the action, approximately 42,240 acres of BLM land were authorized for disposal by sale, exchange, mineral leases, rights-of-way leases, or recreation or public purpose leases. These lands could be developed for residential, industrial, commercial, and public infrastructure projects to accommodate rapid urban development. The biological opinion concluded that the proposed action to implement the BLM's MFP was not likely to jeopardize the continued existence of the Mojave population of the desert tortoise; no critical habitat would be destroyed or adversely modified. Under the 1991 programmatic biological opinion, the BLM disposed of 5,252 acres out of the 42,240 acres originally identified.

File No. 1-5-96-F-023R. In order to expand the programmatic boundary from 263,267 acres to 378,978 acres to accommodate the rapid urban development in the Las Vegas Valley and surrounding area, the BLM reinitiated consultation on their 1991 programmatic biological opinion described above. On April 11, 1996, the Service issued a programmatic biological opinion to the BLM's Las Vegas District for implementation of their MFP and the land exchange portion of their Stateline Resource Management Plan within the Las Vegas Valley. Implementation of these plans, when finalized, may result in disposal or development of approximately 125,000 acres of land administered by the BLM by sale, land exchange, or lease. As a result of urban expansion, most BLM lands within the Las Vegas Valley are highly fragmented and impacted by human activities, particularly a 4,000-acre "exclusionary" zone. The BLM delineated an exclusionary zone within the programmatic boundary which does not contain suitable desert tortoise habitat. Except for lands within the exclusionary zone, the BLM will collect a mitigation fee of $623 per acre, as indexed for inflation, to compensate for the loss of tortoise habitat within the programmatic boundary. The fees will be used to fund management actions which are expected to provide direct and indirect benefits to the desert tortoise over time, which will assist in its recovery. This opinion remains in effect.

File No. 1-5-96-F-33. On August 22, 1996, the Service issued a biological opinion to the Department of Energy/Nevada Operations (DOE/NV) for programmatic activities on the NTS over the next 10 years, excluding the Yucca Mountain Project. The NTS occupies 1,350 square miles in Nye County, approximately 65 miles northwest of Las Vegas. All land on the NTS is managed by DOE/NV, and access is strictly controlled. Between 3,000 and 4,000 people work at the NTS, with the majority residing in Mercury, Nevada. Although large parts of the NTS have been affected by human activities, the majority of the site remains relatively undisturbed. Most disturbances are concentrated in the bottom of Yucca, Frenchman, and Jackass Flats, and on parts of the Pahute and Rainer Mesas. In the biological opinion, the Service concluded that up to 13 desert tortoises may be taken per year (3 mortalities or injuries and 10 captures/displacements from harm's way) as a result of DOE/NV activities, and a total of 3,015 acres of desert tortoise habitat may be disturbed during project construction over the 10-year period.

File No. 1-5-97-F-251. On November 21, 1997, the Service issued a programmatic biological opinion to the BLM for implementation of multiple-use actions within their Las Vegas District, excluding desert tortoise critical habitat, proposed desert tortoise ACECs, and the area covered by the Las Vegas Valley programmatic consultation. The BLM proposes to authorize activities within the programmatic area that may result in loss of tortoises or their habitat through surface disturbance, land disposal, and fencing, for a period of 5 years. The total area covered by this programmatic biological opinion is approximately 2,636,600 acres, which includes approximately 263,900 acres of BLM-withdrawn lands in Clark County. This programmatic consultation is limited to activities which may affect up to 240 acres per project, and a cumulative total of 10,000 acres, of desert tortoise habitat excluding land exchanges and sales. Only land disposals by sale or exchange within Clark County may be covered under this consultation up to a cumulative total of 14,637 acres. Therefore, a maximum total of 24,637 acres of desert tortoise habitat may be affected by the proposed programmatic activities. The BLM collects a remuneration fee of $623 per acre of disturbance of desert tortoise habitat, as indexed for inflation.

File No. 1-5-98-F-053. On June 18, 1998, the Service issued a programmatic biological opinion to the BLM for implementation of the Las Vegas RMP. The BLM collects a remuneration fee of $623 per acre of disturbance of desert tortoise habitat, as indexed for inflation. The project area for this consultation covers all lands managed by the BLM's Las Vegas Field Office, including desert tortoise critical habitat, proposed desert tortoise ACECs, and BLM-withdrawn land. The Las Vegas Field Office designated approximately 648 square miles of tortoise habitat as desert tortoise ACEC in the Northeastern Mojave RU, and approximately 514 square miles of tortoise habitat as desert tortoise ACEC in the East Mojave RU, through the final RMP. As identified in the RMP, the BLM would manage 743,209 acres of desert tortoise habitat within four tortoise ACECs for desert tortoise recovery. To accomplish recovery of the desert tortoise in the Northeastern and Eastern Mojave RUs, the Las Vegas Field Office will implement appropriate management actions in desert tortoise ACECs through the RMP which includes:

1. Manage for zero wild horses and burros within desert tortoise ACECs.

2. Limit utility corridors to 3,000 feet in width, or less.

3. Do not authorize new landfills or military maneuvers.

4. Require reclamation for activities which result in loss or degradation of tortoise habitat, with habitat to be reclaimed so that pre-disturbance condition can be reached within a reasonable time frame.

5. Limit all motorized and mechanized vehicles to designated roads and trails within ACECs and existing roads, trails, and defined dry washes outside ACECs.

6. Allow non-speed OHV events within ACECs, subject to restrictions and monitoring determinations.

7. Prohibit OHV speed events, mountain bike races, horse endurance rides, four-wheel hill climbs, mini-events, publicity rides, high-speed testing, and similar speed based events.

8. Within ACECs, do not allow commercial collection of flora. Only allow commercial collection of fauna within ACECs upon completion of a scientifically credible study that demonstrates commercial collection of fauna does not adversely impact affected species or their habitat. This action will not affect hunting or trapping, and casual collection as permitted by the State.

File No. 1-5-99-F-450. On March 3, 2000, the Service issued a programmatic biological opinion to the Bureau for implementation of the Caliente Management Framework Plan (CMFP). The Bureau collects a remuneration fee of $623 per acre of disturbance of desert tortoise habitat, as indexed for inflation. The planning area for this consultation covers all desert tortoise habitat managed by the Bureau's Ely Field Office and Caliente Field Station within the Ely District. The planning area comprises approximately 754,600 acres of desert tortoise habitat, including 244,900 acres of designated desert tortoise critical habitat. The Bureau's Ely Field Office will implement management actions described in the biological opinion including multiple-use activities. The CMFP was developed to assist in the recovery and delisting of the Mojave population of desert tortoise in the NEMRU. The CMFP designated three ACECs with a total acreage of approximately 212,500 acres (332 square miles) to be managed primarily for recovery of the desert tortoise.

Implementation of actions by the Ely Field Office which may affect desert tortoise include: Livestock grazing; wild horse and burro management; land disposal and acquisition; rights-of-way management; management of recreational activities including OHV use; minerals management; fire management; and public transportation and access. These actions may result in loss of tortoises or their habitat through programmatic activities over a 10-year period.

Habitat Conservation Plans Completed in Nevada

On May 23, 1991, the Service issued a biological opinion on the issuance of incidental take permit PRT-756260 (File No. 1-5-91-FW-40) under section 10(a)(1)(B) of the Act. The Service concluded that incidental take of 3,710 desert tortoises on up to 22,352 acres of habitat within the Las Vegas Valley and Boulder City in Clark County, Nevada, was not likely to jeopardize the continued existence of the desert tortoise. The permit application was accompanied by the *Short-Term Habitat Conservation Plan for the Desert Tortoise in the Las Vegas Valley, Clark County, Nevada* (Regional Environmental Consultants 1991) (short-term HCP) and an implementation agreement that identified specific measures to minimize and mitigate the effects of the action on desert tortoises.

On July 29, 1994, the Service issued a non-jeopardy biological opinion on the issuance of an amendment to incidental take permit PRT-756260 (File No. 1-5-94-FW-237) to extend the expiration date of the existing permit by 1 year (to July 31, 1995) and include an additional disturbance of 8,000 acres of desert tortoise habitat within the existing permit area. The amendment did not authorize an increase in the number of desert tortoises allowed to be taken under the existing permit. Additional measures to minimize and mitigate the effects of the amendment were also identified. Approximately 1,300 desert tortoises were taken under the authority of PRT-756260, as amended. In addition, during the short-term HCP, as amended, approximately 541,000 acres of desert tortoise habitat have been conserved in Clark County on lands administered by the BLM and the National Park Service.

On February 10, 1995, the Service issued an incidental take permit (PRT-776604) to Nye County for development and operation of a landfill near Pahrump, Nevada. The permit authorized take of 20 desert tortoises and loss of 80 acres of tortoise habitat as a result of the landfill for the next 30 years. Over the term of the permit, Nye County shall transfer up to a total of $25,920 into a desert tortoise trust fund as mitigation for the alteration of up to 80 acres of suitable desert tortoise habitat in the project area. These funds shall be used for the purchase, installation, and maintenance of cautionary tortoise road signs. Surplus funds will be used for public education on the Mojave desert and its inhabitants, including the desert tortoise.

On July 11, 1995, the Service issued an incidental take permit (PRT-801045) to Clark County, Nevada, including cities within the county and the Nevada Department of Transportation (NDOT), under the authority of section 10(a)(1)(B) of the Act. The permit became effective August 1, 1995, and allowed the "incidental take" of desert tortoises for a period of 30 years on 111,000 acres of non-Federal land in Clark County, and approximately 2,900 acres associated with NDOT activities in Clark, Lincoln, Esmeralda, Mineral, and Nye Counties, Nevada. The *Clark County Desert Conservation Plan* (CCDCP) (Regional Environmental Consultants 1995), served as the permitees' habitat conservation plan and detailed their proposed measures to minimize, monitor, and mitigate the effects of the proposed take on the desert tortoise. The permittees imposed, and NDOT paid, a fee of $550 per acre of habitat disturbance to fund these measures. The permittees expended approximately $1.65 million per year to minimize and mitigate the potential loss of desert tortoise habitat. The majority of these funds were used to implement minimization and mitigation measures, such as increased law enforcement; construction of highway barriers; road designation, signing, closure, and rehabilitation; and tortoise inventory and monitoring within the lands initially conserved during the short-term HCP and other areas being managed for tortoise recovery (e.g., ACECs or DWMAs). The benefit to the species, as provided by the CCDCP, substantially minimized and mitigated those effects which occurred through development within the permit area and aided in recovery of the desert tortoise.

On November 22, 2000, the Service issued an incidental take permit (TE-034927-0) to Clark County, Nevada, including cities within the county and the NDOT, under the authority of section 10(a)(1)(B) of the Act. The permit supercedes the incidental take permit for the CCDCP. The new permit allows the "incidental take" of the federally threatened desert tortoise, the federally endangered southwestern willow flycatcher (*Empidonax traillii extimus*), and 76 currently unlisted species for a period of 30 years on 145,000 acres of non-Federal land in Clark County, and within NDOT rights-of-way, south of the 38th parallel in Nevada. The *Clark County Multiple Species Habitat Conservation Plan and Environmental Impact Statement* (MSHCP) (Clark County and Service 2000), serves as the permitees' habitat conservation plan and details their proposed measures to minimize, monitor, and mitigate the effects covered activities on the 78 species. In addition to measures specified in the MSHCP and its implementing agreement, the permittees shall comply with the special terms and conditions of the permit and measures stated in sections 3C and 3D of the CCDCP, which were incorporated by reference into the MSHCP and incidental take permit.

Yucca Mountain does not include private land and occurs in Nye County, therefore the project area occurs outside Clark County's incidental take permit areas for the CCDCP and MSHCP.

Effects of the Proposed Action on the Listed Species

Implementation of the proposed action would result in the loss of up to 1,643 acres of low-density desert tortoise habitat. Increased human use and development of the desert often result in more human interactions with the desert tortoise and its habitat. Extensive disturbance may result in dispersal of tortoises into surrounding areas which are poor to very poor habitat (Karl 1989). Overall, desert tortoise habitats most susceptible to negative impacts are those at the interfaces between developed lands and open desert. Habitat fragmentation associated with development is a major contributor to population declines throughout the range of the tortoise (Berry and Burge 1984). Even near small settlements (e.g., Mercury) and isolated residences the same factors are present, and the cumulative impacts can spread in a radius of several miles from such areas. For example, domestic dogs can be found digging up and killing desert tortoises several miles from home (Service 1994).

Disturbance of desert tortoise habitat during construction of facilities, excavation of trenches, and creation of drill pads are the most obvious effects to desert tortoise. Desert tortoises may be buried in their burrows as a result of road construction and maintenance, killed or injured by project vehicles, drowned by water discharges into washes, trapped or injured by falling into open holes or trenches, or captured and displaced out of harm's way. Additional harassment may occur from increased levels of human activity, noise, and ground vibrations produced by vehicles and heavy equipment (Bondello 1976; Bondello et al. 1979). Desert tortoises may be captured by workers for use as pets. Ground vibrations can cause desert tortoises to emerge from their burrows; slapping the ground several times within a few feet of a desert tortoise burrow entrance will often cause a desert tortoise to emerge (Medica et al. 1986). The measures proposed by DOE to implement a tortoise education program, conduct preactivity and clearance surveys, impose speed limits, and cease activities that threaten a tortoise until the tortoise moves or is moved out of harm's way should minimize these effects.

Yucca Mountain occurs within a restricted access area which prevents tortoises from being collected or harassed by the public. The release of captive animals which are ill may contribute to the spread of URTD or other diseases in wild populations (Jacobson et al. 1995; Jacobson and Gaskin 1990). Because Yucca Mountain is an isolated and restricted access area, the potential introduction of disease to tortoises in the area through release of captive desert tortoises by the public is unlikely.

A survey of approximately 54 miles of electrical transmission lines in southern Nevada produced the remains of 78 juvenile tortoises which were found beneath 23 towers (McCullough Ecological Systems 1995). Ravens use power transmission towers and other man-made structures for perches to locate small, slow-moving hatchling and juvenile tortoises. Natural predation in undisturbed, healthy ecosystems is generally not an issue of concern. However, predation rates may be altered when natural habitats are disturbed or modified. Construction of artificial raven perch and nest sites (e.g., power transmission lines) may increase raven predation of desert tortoises. Roads may provide linear open areas that make tortoises more visible to avian predators. Common raven populations in the California deserts have increased ten-fold from 1968 to 1992 in response to expanding human use of the desert (Boarman and Berry 1995). Because ravens make frequent use of food, water, and nest site subsidies provided by humans, their population increases can be tied to this increase in food and water sources, such as landfills and septic ponds (Boarman 1992; Service 1994). Ravens may be attracted to landfills or project sites if trash is accessible by scavengers (Berry 1985; BLM 1990). Considering that ravens were very scarce in this area prior to 1940, it is assumed that the current level of raven predation on juvenile desert tortoises is an unnatural occurrence (BLM 1990).

Beginning in August 1991 and continuing for 32 months, DOE initiated a raven abundance and monitoring program. During the program, project biologists determined that there was no change in the difference between the number of ravens observed between pre- and post-disturbance (Holt and Mueller 1994). No tortoise carcasses were observed under utility poles or raven nest sites. Because ravens occur at Yucca Mountain and potentially may prey on small tortoises, DOE proposes to continue to implement a litter-control program and manage landfills in a manner which minimizes potential attraction of ravens to the Yucca Mountain.

Desert tortoises will continue to be threatened by roads and vehicles on the project site and access roads. Data from permanent study plots in California show that tortoise densities decreased significantly with increasing mileage of linear disturbances (e.g., roads), increasing numbers of human visitors, and increasing percentages of introduced annual plants (Berry 1992). The density of roads, routes, trails, and ways in desert tortoise habitat has a direct effect on mortality rates and losses of tortoises. Access allows people to penetrate into remote, undisturbed parts of the desert, which contributes to tortoise mortality and habitat loss or degradation (Service 1994). During 1991-1996, four (4) tortoises were reported killed on NTS roads. Movement of tortoises out of imminent danger on roads as authorized by previous biological opinions for the project site and NTS should minimize injury and mortality of tortoises.

Implementation of activities as described in the Plan may result in the long-term disturbance of an additional 1,643 acres of desert tortoise habitat beyond prior project activities. The Service believes that no more than fifteen (15) desert tortoises may be incidentally killed or injured during the proposed action, and up to sixty (60) tortoises captured/displaced as a result of the proposed project.

The Service has determined that the level of effect described herein will not reduce appreciably the likelihood of survival and recovery of the Mojave population of the desert tortoise in the wild or diminish the value of critical habitat both for survival and recovery of the desert tortoise because:

(1) The proposed project area does not occur within any areas recommended for recovery of the desert tortoise or areas designated as critical habitat;

(2) rehabilitation and revegetation of disturbed sites will minimize many of the long-term effects of the proposed project on the desert tortoise;

(3) DOE has made a substantial investment of resources to conserve the desert tortoise at Yucca Mountain. With proper management and continued conservation, desert tortoise populations at Yucca Mountain will remain viable; and;

(4) the project area occurs within the Northeastern RU in Nye County, Nevada. Project activities should not result in a substantial loss of the tortoises within this RU when total desert tortoise population numbers and geographical extent are considered.

Cumulative Effects

Cumulative effects are those effects of future non-Federal (State, local government, or private) activities that are reasonably certain to occur in the project area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act.

The project area occurs on public land with access restrictions in Nye County. Any future actions on these lands, including Federal transportation rights-of-way and funding in support of the proposed project, will be subject to consultation under section 7 of the Act.

Conclusion

After reviewing the current status of the desert tortoise, the environmental baseline for the project area, the effects of the proposed action and the cumulative effects, it is the Service's biological opinion that construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain is not likely to jeopardize the continued existence of the threatened Mojave population of the desert tortoise. These actions do not affect any area designated as critical habitat; therefore, no destruction or adverse modification of that habitat is anticipated.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act, as amended, prohibits take (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct) of listed species of fish or wildlife without a special exemption. "Harm" is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering (50 CFR § 17.3). "Harass" is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR § 17.3). Incidental take is any take of listed animal species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant. Under the terms of sections 7(b)(4) and 7(o)(2) of the Act, taking that is incidental to and not intended as part of the agency action is not considered a prohibited taking provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The Service hereby incorporates by reference DOE's six proposed measures from the *Description of the Proposed Action* into this incidental take statement as part of these terms and conditions. The following terms and conditions: (1) Restate measures proposed by DOE, (2) modify the measures proposed by DOE, or (3) specify additional measures considered necessary by the Service.. Where these terms and conditions vary from or contradict the measures proposed under the *Description of the Proposed Action*, specifications in these terms and conditions shall apply. The measures described below are nondiscretionary and must be implemented by DOE so that they become binding conditions of any project, contract, grant, or permit issued by DOE, as appropriate, in order for the exemption in section 7(o)(2) to apply.

DOE has a continuing duty to regulate the activity that is covered by this incidental take statement. If DOE fails to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, and/or fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

Amount of Take

Based on the analysis of impacts provided above, measures proposed by DOE, and anticipated project duration, the Service anticipates that the following take could occur as a result of the proposed action:

1. Fifteen (15) desert tortoises may be accidentally injured or killed onsite during project-related activities as a result of the proposed action. An unknown number of desert tortoises may be killed or injured on project-related roads, however the Service anticipates that fewer than five tortoises per year would be killed on injured on these roads.

2. All desert tortoises encountered within the project area or roads associated with the project may be taken by capture and movement out of harm's way; the Service estimates that no more than sixty (60) desert tortoise will we captured and moved during the project.

3. An unknown number of desert tortoises may be taken in the form of indirect mortality through predation by ravens drawn to the project area.

4. An unknown number of desert tortoise eggs and non-emerged hatchlings may be moved or incidentally destroyed as a result of the project activities.

5. An unknown number of desert tortoises may be taken indirectly in the form of harm or harassment through increased noise associated with operation of heavy equipment.

A total of 1,643 acres of desert tortoise habitat may be destroyed as a result of the proposed action, in addition to the 375 acres disturbed under the previous biological opinions (File Nos. 1-5-90-F-6 and 1-5-96-F-307R).

Effect of the Take

In the accompanying biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

Reasonable and Prudent Measures

The Service believes that the following reasonable and prudent measures are necessary and appropriate to minimize take of desert tortoise:

1. Measures shall be taken to minimize take of desert tortoises due to project-related activities and operation of heavy equipment.

2. Measures shall be taken to minimize entrapment of desert tortoises in open trenches.

3. Measures shall be taken to minimize predation on tortoises by ravens drawn to project areas.

4. Measures shall be taken to minimize destruction of desert tortoise habitat, such as soil compaction, erosion, or crushed vegetation, due to project-related activities.

5. Measures shall be taken to ensure compliance with the reasonable and prudent measures, terms and conditions, reporting requirements, and reinitiation requirements contained in this biological opinion.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, DOE must fully comply with the following terms and conditions, which implement the reasonable and prudent measures described above.

1. To implement Reasonable and Prudent Measure Number 1, DOE shall fully implement the following measures:

   a. Clearance surveys will be conducted by qualified biologists prior to clearing of vegetation at previously undisturbed sites if new disturbances are larger than 5 acres or records indicate tortoises may occur in the area to be disturbed. If the project activity can occur in an adjacent area where no tortoises or sign are present, the proposed activity shall be moved. If no suitable site is totally free of tortoises or tortoise sign, the qualified biologist shall determine which site would cause the least impact to tortoises and their habitat.

In accordance with *Procedures for Endangered Species Act Compliance for the Mojave Desert Tortoise* (Service 1992), a qualified desert tortoise biologist shall possess a bachelor's degree in biology, ecology, wildlife biology, herpetology, or closely related fields. The biologist must have demonstrated prior field experience using accepted resource agency techniques to survey for desert tortoises and tortoise sign. In addition, the biologist shall have the ability to recognize and accurately record survey results.

b. Clearance surveys will be conducted either the day prior to, or the day of, any surface-disturbing activity during the tortoise activity season (February 16 through November 14). Based on the results of the hibernation study conducted at the Yucca Mountain Site Characterization Project (Rautenstrauch et al. 1997), the Service anticipates that most tortoises will be in hibernacula during the inactive season and will remain there during a 7-day period between survey and activity. Therefore, clearance surveys will be conducted within 7 days prior to any surface-disturbing activity during the hibernation period (November 15 through February 15). Qualified desert tortoise biologists will search areas to be cleared using techniques providing 100-percent coverage of all areas to be disturbed, as described in Term and Condition 1.a. above. If tortoises or eggs are found during clearance surveys, they will be moved out of harm's way following Service guidelines (Desert Tortoise Council 1994, revised 1999). All tortoise burrows, and other animal burrows that may be used by tortoises, that are found during clearance surveys will be conspicuously flagged and avoided by at least 30 feet.

c. If a burrow cannot be avoided, it will be inspected to determine the presence of tortoises or tortoise nests. If unoccupied, the burrow will be collapsed to prevent tortoise entry. All unavoidable burrows containing tortoise eggs or tortoises will be excavated by hand to remove the tortoise and/or eggs. Tortoise eggs and tortoises in harm's way will be removed and relocated by qualified biologists and handled according to desert tortoise handling procedures approved by the Service. (Currently, the approved procedures are in: Desert Tortoise Council 1994, revised 1999).

d. If removed from a burrow, the tortoise will be placed in the shade of a shrub or in an existing, similar, unoccupied tortoise burrow that is approximately the same size, depth, and orientation as the original burrow. Desert tortoises moved during the tortoise inactive season (i.e., November 15 through February 15), or those considered by the qualified desert tortoise biologist to be in estivation or brumation, regardless of date, must be placed into an adequate burrow. If suitable, unoccupied burrow (i.e., similar in size, depth, and orientation as the original burrow) is not available, one will be constructed utilizing the protocol for burrow construction in section B.5.f of the Service-approved guidelines (Desert Tortoise Council 1994, revised 1999).

e. Project activities that may endanger a tortoise will cease if a tortoise is found on a project site. Project activities will resume after the biologist removes the tortoise from danger or after the tortoise has moved to a safe area.

f. A tortoise biologist or environmental monitor (in place of a desert tortoise biologist) will be onsite during all phases of each construction activity to ensure construction activities are in compliance with this biological opinion and that desert tortoises are not inadvertently harmed.

The environmental monitor may be the project foreman or supervisor who will be responsible for: (1) Enforcing the litter-control program; (2) ensuring that tortoise-proof fences are maintained where applicable; (3) ensuring that desert tortoise habitat disturbance is restricted to authorized areas; (4) ensuring that all equipment and materials are stored within the boundaries of the construction zone or within the boundaries of previously disturbed areas; (5) ensuring that all vehicles associated with construction activities are using existing graded or paved roads or are within the proposed construction zones; (6) ensuring that open trenches or other excavations are inspected in accordance with term and condition 2 of this biological opinion; (7) ensuring that speed limits are observed; and (8) ensuring compliance with the terms and conditions of this biological opinion. An environmental monitor is not authorized to handle tortoises, which will only be done by a qualified desert tortoise biologist.

g. Vehicles will not be driven off existing roads in non-emergency situations unless authorized by DOE. During the tortoise active season (February 15 through November 15) the proposed vehicle path will be cleared of tortoises immediately prior to off-road travel. During the tortoise inactive season, the proposed vehicle path will be flagged and cleared of tortoises within 7 days prior to off-road travel.

h. All vehicles will be driven at speeds within the posted speed limits on existing roads, and will not exceed 25 miles per hour on unposted roads.

Main Index

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I. DOE will continue to present a tortoise education program to all workers and employees working on the project site. This will include information on the life history of the desert tortoise, legal protection for desert tortoises, penalties for violations of Federal and State laws, general tortoise activity patterns, reporting requirements, measures to protect tortoises, and personal measures employees can take to promote the conservation of desert tortoises. The definition of "take" will also be explained. All questions on desert tortoises or actions which may affect tortoise will be answered accurately by the instructor or a qualified tortoise biologist. All DOE and contractor personnel working on the project at Yucca Mountain will complete the DOE tortoise education program.

The education program shall instruct attendees that the definition of "take" includes capture. Therefore, any unauthorized person who picks up a desert tortoise or restricts the animal's ability to move freely, could be found guilty of illegal "take" unless done in accordance with this biological opinion. The same applies for any individual if the authorized level of incidental take has been reached or exceeded. Any action taken to harm, harass, pursue, hunt, shoot, wound, kill, collect, capture, or trap a tortoise, or attempt to conduct any of these activities constitutes take.

Incidental take occurring which is consistent with the *Incidental Take Statement* of this biological opinion would be legal; for example, moving a tortoise out of the path of an approaching vehicle if the tortoise is observed in the road within the project area. However, the tortoise may not be moved if it is not in imminent danger and will leave the road of its own accord. If a tortoise must be moved off a road to avoid imminent injury or mortality, the tortoise must be moved in the same direction of travel. The tortoise shall be picked up gently with two hands, kept level, and carried close to the ground. The tortoise shall be placed in the shade of a shrub approximately 25 feet from the road edge.

j. Marking or radiotelemetry of desert tortoises is not authorized under this biological opinion. Tortoises shall be purposefully moved only by qualified tortoise biologists, solely for the purpose of moving them out of harm's way, with the exception identified in 1.i. above.

2. To implement Reasonable and Prudent Measure Number 2, DOE shall fully implement the following measures:

a. During the tortoise active season (February 16 through November 14), all trenches and other excavations with side slopes steeper than 1-foot rise to 3-foot length shall be immediately backfilled prior to being left unattended, or: (1) Fenced with tortoise-proof fencing; (2) covered with tortoise-proof fencing; (3) covered with plywood or similar material; or (4) constructed with escape ramps at each end of the trench and every 1,000 feet, at a minimum. All coverings and fences shall have zero ground clearance. If alternative 4 is selected, the trench or other excavation will be inspected periodically and following periods of substantial rainfall to ensure structural integrity and that escape ramps are functional.

b. An open trench or other excavation as described in 2.a. shall be inspected for entrapped animals immediately prior to backfilling.

c. If at any time a tortoise is discovered within a trench, all activity associated with that trench shall cease until a qualified biologist has removed the tortoise in accordance with Service-approved guidelines (Desert Tortoise Council 1994, revised 1999).

3. To implement Reasonable and Prudent Measure Number 3, DOE shall fully implement the following measure:

   DOE will implement a litter-control program that will include the use of covered, raven-proof trash receptacles; disposal of edible trash in trash receptacles following the end of each work day; and disposal of trash in a designated sanitary landfill at the end of each week or when nearly full. Material placed in a sanitary landfill will be covered often enough to prevent ravens and other predators from feeding in the area.

4. To implement Reasonable and Prudent Measure Number 4, DOE shall fully implement the following measure:

   Project areas no longer required by the project will be revegetated in accordance with the *Reclamation Implementation Plan* (Reclamation Plan) (DOE 2001c), RSMP (DOE 1998) developed for the Yucca Mountain Site Characterization Project, and recommendations made by Rakestraw et al. (1995). Site-specific plans will be developed for each site to be rehabilitated and shall conform with the Reclamation Plan and RSMP. Only native perennial vegetation and annual plants, including forage species of desert tortoises will be used on the project site. DOE shall conduct a field survey at each site and develop site-specific reclamation plans for surface-disturbing projects within desert tortoise habitat. These plans may include specifications for contouring, relieving soil compaction, treating and/or spreading topsoil, and planting. In addition, these plans will describe in specific detail how disturbed sites will be rehabilitated using reasonable state-of-the-art techniques.

5. To implement Reasonable and Prudent Measure Number 5, DOE shall fully implement the following measures:

   a. Prior to handling any desert tortoise, carcass, or egg, appropriate State permits will be acquired from the Nevada Division of Wildlife.

   b. DOE will designate a field contact representative for each project, which may also serve as the environmental monitor, if appropriate. The field representative will be responsible for overseeing compliance with protective stipulations for the desert tortoise and for coordinating compliance with the terms and conditions of this biological opinion. The field representative will have the authority to halt activities of construction equipment which may be in violation of the stipulations.

   c. DOE will keep an up-to-date log of all actions taken under this consultation, including acreage affected, habitat rehabilitation actions completed, number of desert tortoises taken and by what means (e.g., injured, killed, captured and displaced, or found in trenches or pits). DOE will provide the above information to the Service's Las Vegas Office on February 28 of every year during which activities occur under this biological opinion. The first annual report will be due February 28, 2002. Information provided in the report shall state cumulative totals, as well as totals for the report year.

The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the anticipated incidental take that may result from the proposed action. With implementation of these measures, the Service believes that no more than fifteen (15) desert tortoises may be incidentally killed or injured, and up to sixty (60) desert tortoises captured and displaced during the proposed project. An additional 1,643 acres of desert tortoise habitat may be disturbed as a result of project activities.

If, during the course of the action, the level of incidental take or loss of habitat identified is exceeded, reinitiation of consultation will be required. DOE must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measures.

Reporting Requirements

Upon locating a dead or injured endangered or threatened species, initial notification must be made to the Service's Division of Law Enforcement in Las Vegas, Nevada, at (702) 388-6380. Care should be taken in handling sick or injured desert tortoises to ensure effective treatment and care or the handling of dead specimens to preserve biological material in the best possible state for later analysis of cause of death. In conjunction with the care of sick or injured desert tortoises or preservation of biological materials from a dead animal, the finder has the responsibility to carry out instructions provided by the Service's Division of Law Enforcement to ensure that evidence intrinsic to the specimen is not unnecessarily disturbed. All deaths, injuries, and illnesses of desert tortoises, whether associated with project activities or not, will be summarized in the annual report.

The following actions should be taken for injured or dead tortoises if directed by the Service's Division of Law Enforcement:

> Injured desert tortoises shall be delivered to any qualified veterinarian for appropriate treatment or disposal. Dead desert tortoises suitable for preparation as museum specimens shall be frozen immediately and provided to an institution holding appropriate Federal and State permits per their instructions. Should no institutions want the desert tortoise specimens, or if it is determined that they are too damaged (crushed, spoiled, etc.) for preparation as a museum specimen, then they may be buried away from the project area or cremated, upon authorization by the Service's Division of Law Enforcement. DOE, or the project proponent, shall bear the cost of any required treatment of injured desert tortoises, euthanasia of sick desert tortoises, or cremation of dead desert tortoises. Should sick or injured desert tortoises be treated by a veterinarian and survive, they may be transferred as directed by the Service.

Conservation Recommendations

Section 7(a)(1) of the Act directs Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

> *The Service recommends that DOE continue to consider important desert tortoise habitat at Yucca Mountain during the development and transportation phases of the project.*

In order for the Service to be kept informed of actions that either minimize or avoid adverse effects or that benefit listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

Reinitiation Notice

This concludes formal consultation on the actions outlined in your April 24, 2000, request. As required by 50 CFR § 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over an action has been retained (or is authorized by law) and if: (1) The amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion (e.g., a substantial number of tortoises are killed or injured on established access roads, particularly along a specific road section); (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

If we can be of any further assistance, please contact Michael Burroughs, in the Southern Nevada Field Office, at (702) 647-5230.

Sincerely,

for Robert D. Williams
Field Supervisor

cc:
Administrator, Nevada Division of Wildlife, Reno, Nevada
Manager, Nevada Division of Wildlife, Las Vegas, Nevada
Deputy Director, Environmental Management, Department of the Air Force, Nellis AFB, Nevada
Deputy State Director, Resources, Land Use and Planning, Bureau of Land Management, Reno, Nevada
Project Leader, Desert National Wildlife Refuge Complex, Fish and Wildlife Service, Las Vegas, Nevada
Assistant Regional Director, Ecological Services, Fish and Wildlife Service, Portland, Oregon
Senior Resident Agent, Division of Law Enforcement, Fish and Wildlife Service, Boise, Idaho

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CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor	
exa-	E	1,000,000,000,000,000,000	= 10^{18}
peta-	P	1,000,000,000,000,000	= 10^{15}
tera-	T	1,000,000,000,000	= 10^{12}
giga-	G	1,000,000,000	= 10^{9}
mega-	M	1,000,000	= 10^{6}
kilo-	k	1,000	= 10^{3}
deca-	D	10	= 10^{1}
deci-	d	0.1	= 10^{-1}
centi-	c	0.01	= 10^{-2}
milli-	m	0.001	= 10^{-3}
micro-	µ	0.000 001	= 10^{-6}
nano-	n	0.000 000 001	= 10^{-9}
pico-	p	0.000 000 000 001	= 10^{-12}

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Final

Environmental Impact Statement

for a

Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Volume IV

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250

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ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the U.S. Department of Energy (DOE) limited the use of acronyms and abbreviations in this environmental impact statement. In addition, acronyms and abbreviations are defined the first time they are used in each chapter or appendix. The acronyms and abbreviations used in the text of this document are listed below. Acronyms and abbreviations used in tables and figures because of space limitations are listed in footnotes to the tables and figures.

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
LCF	latent cancer fatality
MTHM	metric tons of heavy metal
NEPA	National Environmental Policy Act, as amended
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act, as amended
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
REMI	Regional Economic Models, Inc.
RMEI	reasonably maximally exposed individual
Stat.	United States Statutes
TSPA	Total System Performance Assessment
U.S.C.	United States Code

UNDERSTANDING SCIENTIFIC NOTATION

DOE has used scientific notation in this EIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number between 1 and 10 and a positive or negative power of 10. Examples include the following:

Positive Powers of 10
$10^1 = 10 \times 1 = 10$
$10^2 = 10 \times 10 = 100$
and so on, therefore,
10^6 = 1,000,000 (or 1 million)

Negative Powers of 10
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/100 = 0.01$
and so on, therefore,
10^{-6} = 0.000001 (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are three chances in 1,000,000 that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.

CONTENTS

Appendix H

Potential Repository Accident Scenarios: Analytical Methods and Results

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APPENDIX H. POTENTIAL REPOSITORY ACCIDENT SCENARIOS: ANALYTICAL METHODS AND RESULTS

This appendix describes the methods and detailed results of the analysis the U.S. Department of Energy (DOE) performed for the Yucca Mountain Repository Environmental Impact Statement (EIS) to assess impacts from potential accident scenarios at the proposed repository. The methods apply to repository accidents that could occur during preclosure only, including operation and monitoring, retrieval, and closure. In addition, this appendix describes the details of calculations for specific accidents that the analysis determined to be credible. Appendix J describes the analytical methods and results for accidents that could occur at the 72 commercial and 5 DOE sites and during transportation to the proposed repository.

The accident scenarios in this analysis, and the estimated impacts, are based on current information from the repository design (DIRS 147496-CRWMS M&O 2000, all). The results are based on assumptions and analyses that were selected to ensure that the impacts from accident scenarios are not likely to be underestimated. DOE has not developed the final design and operational details for the repository, and these details could result in lower impacts. The Department intends to identify accidents and evaluate their impacts as required to support the License Application for the proposed repository that it would send to the Nuclear Regulatory Commission, and to show that the repository would comply with appropriate limits on radiation exposure to workers and the public from accidental releases of radionuclides. The final design could include additional systems and operational requirements to reduce the probability of accidents and to mitigate the release of radionuclides to ensure compliance with these safety requirements. To meet licensing requirements, the results from the accident analysis would be more specific and comprehensive than those discussed in this appendix and would reflect final repository design and operational details.

H.1 General Methodology

Because of the large amount of radioactive material to be handled at the proposed repository (see Appendix A), the focus of the analysis was on accident scenarios that could cause the release of radioactive material to the environment. The methodology employed to estimate the impact of accidents involving radioactive material included (1) evaluation of previous accident analyses performed for the repository, (2) identification of bounding accidents (reasonably foreseeable accidents with the maximum consequences) from the previous analyses, (3) identification of other credible accidents the previous analyses did not evaluate, (4) analyses of the selected accidents to determine the amount of radioactive material an accident could release to the environment, and (5) estimation of the consequences of the release of radioactive material in terms of health effects to workers and the public.

The analysis approach involved identifying bounding accidents (that is, accidents with maximum consequences) for each operational phase of the proposed repository. The analysis evaluated the impacts for these accidents, assuming the accident occurred without regard to the estimated probability. Thus, the analysis provides the impacts that could occur for the worst credible accidents. The results do not represent risk estimates because the impacts do not include a consideration of accident probability, which in most cases is very low.

Accident frequency estimates were derived to establish the credibility of accident sequences and were not used to establish risk. Estimates of accident frequency are very uncertain due to the preliminary nature of the currently available repository design information and would be more fully evaluated in the safety analysis required to support a License Application for the repository. Based on the available design information, the accident analysis approach was used to ensure that impacts from accidents are not likely to be underestimated (whether they are low-probability with high-consequence accidents or high-probability with low-consequence accidents).

For accidents not involving radioactive materials, the analysis determined that application of accident statistics from other DOE operations provided a reasonable estimate of nonradiological accident impacts (see Section H.2.2).

H.2 Potential Repository Accident Scenarios

The proposed Yucca Mountain Repository has been the subject of intense evaluations for a number of years. Some of these evaluations included in-depth considerations of preclosure accidents that could occur during repository operations. The EIS used these previous evaluations, to the extent they are applicable and valid, to aid in the identification of initiating events, develop sequences, and estimate consequences. The EIS groups accidents as radiological accidents (Section H.2.1) that involve the unplanned release of radioactive material, and nonradiological accidents that involve toxic and hazardous materials (Section H.2.2).

H.2.1 RADIOLOGICAL ACCIDENT SCENARIOS

Previous analyses that considered impacts of radiological accidents during preclosure included evaluations by Sandia National Laboratories and others (DIRS 104699-Jackson et al. 1984, all; DIRS 100181-SNL 1987, all; DIRS 101930-Ma et al. 1992, all; DIRS 104693-Yook et al. 1984, all). More recent evaluations include DIRS 104695-CRWMS M&O (1996, all); DIRS 100204-CRWMS M&O (1996, all); DIRS 100217-CRWMS M&O (1997, all); DIRS 102702-CRWMS M&O (1997, all); DIRS 103237-CRWMS M&O (1998, all); DIRS 147496-CRWMS M&O (2000, all); DIRS 150276-CRWMS M&O (2000, all); DIRS 149759-CRWMS M&O (1999, all); and DIRS 137064-CRWMS M&O (1999, all). These evaluations were reviewed to assist in this assessment of radiological impacts from accidents during repository operations. In addition, EISs that included accident evaluations involving spent nuclear fuel and high-level radioactive waste were reviewed and used as applicable (DIRS 101941-USN 1996, all; DIRS 103213-DOE 1996, all).

Radiological accidents involve an initiating event that could lead to a release of radioactive material to the environment. The analysis considered accidents separately for two types of initiating events: (1) internal initiating events that would originate in the repository and involve equipment failures or human errors, or a combination of both, and (2) external initiating events that would originate outside the facility and affect the ability of the facility to maintain confinement of radioactive or hazardous material. The analysis examined a spectrum of accidents, from high-probability/low-consequence accidents to low-probability/higher-consequence accidents. In addition to these credible accidents, DOE evaluated a repository aircraft crash event. Even though such an event was determined to be not credible (annual probability less than one in 10 million), DOE decided to evaluate it because such an accident could have large impacts. The results of the evaluation are presented in Section H.2.1.5.1.

H.2.1.1 Internal Events – Waste Handling Building and Emplacement System

The most recent repository accident scenario analysis for internal and external events in the Waste Handling Building (DIRS 155734-DOE 2001, pp. 5-1 to 5-48) addressed Nuclear Regulatory Commission requirements in 10 CFR Part 63. The analysis was a comprehensive evaluation of repository operations to identify accident sequences that could lead to a radioactive release. Detailed analyses involving the use of event trees and fault trees were performed on the sequences to estimate accident frequencies. The frequency evaluation was used to identify Category 1 accidents (a frequency of once per 100 years or

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greater), Category 2 accidents (a frequency of between once in 100 years and once in 1 million years), or beyond-design-basis events (a frequency less than once in 1 million years).

A review of these evaluations indicated that they were valid for use in the EIS with a few exceptions and revisions (noted below).

The evaluation used to identify internal accidents did not evaluate criticality events (see Glossary for event description) quantitatively (DIRS 103237-CRWMS M&O 1998, p. 34). Continuing evaluations are under way to assess the probability and consequences of a criticality event. The risk from criticality events, however, would be unlikely to exceed the risk from the bounding events considered below. This preliminary conclusion is based on several factors:

RISK

Risk is defined as the possibility of suffering harm. It considers both the frequency (or probability) and consequences of an accident. In the scientific community, risk is usually computed as the product of the frequency of an accident and the consequences that result.

Rather than develop a single, overall expression of the risks associated with proposed actions, DOE usually finds it more informative in its EIS accident scenario analyses to consider a spectrum of accidents from low-probability, relatively high-consequence accidents to high-probability, low-consequence accidents. Nevertheless, risk is a valuable concept to apply in evaluating the spectrum of accident scenarios to ensure that accidents that are expected to dominate risk have been adequately considered.

- The probability of a criticality event would be very low. This is based on the Nuclear Regulatory Commission design requirement that specifies that two independent low-probability events must occur for criticality to be possible and that this requirement will be part of the licensing basis for the repository. On the basis of this requirement, the event is unlikely to be credible (DIRS 104699-Jackson et al. 1984, p. 18). Further, a criticality event would require the assembly of fuel with sufficient fissionable material to sustain a criticality. Since the commercial spent-nuclear fuel to be handled at the repository is spent (that is, it has been used to produce power), the remaining fissionable material is limited. For the pressurized-water reactor fuel, the amount of fuel that contains sufficient fissionable material to achieve criticality is only a small percent of the spent nuclear fuel (DIRS 104441-YMP 1998, p. C-46). This material would have to be assembled in sufficient quantity to achieve criticality, and the moderator (water) would somehow have to be added to the assembled material. A quantitative estimate of criticality frequency is planned as part of the license application (DIRS 103237-CRWMS M&O 1998, p. 34).

- The criticality event that could occur despite the preventive measures described above would be unlikely to compromise the confinement function of the ventilation and filtration system of the Waste Handling Building. These features would inhibit the release of particulate radionuclides. By contrast, the seismic event scenario (discussed in Section H.2.1.3) assumes failure of these mitigating features.

- Criticality could occur if the material was moderated with water and had sufficient fissionable material in a configuration that could allow criticality. The water surrounding the material would act to inhibit the release of particulate material (DIRS 103683-DOE 1994, Volume 1, Appendix D, p. F-85) and, thus, would limit the source term.

- During the monitoring and closure phase of operations, water would have to enter a waste package that contained fuel with sufficient fissionable material to cause a criticality. Water would have to flood a drift and leak into a defective waste package to cause a criticality. Such an event is considered not credible due to the lack of sufficient water sources, detection and remediation of water in-leakage, and high-quality leak proof waste packages.

- Evaluated criticality events (DIRS 147496-CRWMS M&O 2000, pp. 5-41 and 5-42) would be beyond-design-basis events with a frequency of less than once in 1 million years (probability of less than 0.000001 per year). Accordingly, DOE did not evaluate these events further as part of the safety assessment process to evaluate compliance with Nuclear Regulatory Commission safety regulations.

Considering these factors, the criticality event is not expected to be a large potential contributor to risk.

Table H-1 lists the accidents that DOE considered for analysis in this EIS. Section A of the table lists the Category 1 accidents as derived in DIRS 147496-CRWMS M&O 2000, p. 5-21, Section B lists the Category 2 accidents from the *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation* (DIRS 147496-CRWMS M&O 2000, p. 5-22), and Section C lists the accidents retained for analysis from the Draft EIS. Some of these accidents were eliminated from further consideration based on evaluations discussed later in this section.

The No. column in Table H-1 provides a numerical identifier that corresponds to the identifier used in the source document. The Location column lists the repository location designator where the accident is assumed to occur. The Accident column describes the accident. The MAR column lists the material at risk; that is, the amount of radioactive material involved in the accident. The Frequency column lists an estimate of the annual probability of the accident. The EIS disposition column describes whether the accident was retained for further analysis, bounded by another accident in the table, or eliminated from further consideration based on other reasons such as design change or reduced probability estimates. The basis for these evaluations is provided in subsequent sections of this appendix.

DOE selected fuel from pressurized-water reactors for most of the accident analyses because it would be the predominant fuel handled at the proposed repository (Appendix A, p. A-15), and because this fuel would produce higher doses than boiling-water reactor fuel (see Section H.2.1.4.4) for equivalent accidents. The analysis retained one accident involving boiling-water reactor fuel (Table H-1, No. 13) to confirm this conclusion (see Section H.2.1.5).

The following paragraphs contain details of the postulated accident scenarios in each location.

H.2.1.1.1 *Cask/Carrier Transport and Handling Area*

DOE would handle incoming transportation casks in the Cask/Carrier Transport and Handling Area. The casks would be unloaded from carriers and impact limiters would be removed to facilitate handling of the casks. The Draft EIS conservatively assumed that damage to the casks would occur if they were dropped from heights greater than 2 meters (6.6 feet) after removal of the impact limiters. Accordingly, four accidents were defined (Numbers 1, 3, 5, and 7 from Table H-1) for analysis. However, DOE has determined that transportation casks would be unlikely to be damaged if dropped from the maximum heights (7.1 meters or 23 feet) to which the casks would be lifted during handling operations. A recent analysis of transportation cask response under accident conditions concluded (DIRS 152476-Sprung et al. 2000, p. 2-7) that truck cask seals are not compromised by impacts at any orientation onto an unyielding surface at speeds as high as at least 145 kilometers (90 miles) per hour even assuming that the impact limiters are fully crushed before the impact. For rail casks (DIRS 154930-NRC 2000, p. 2-8), seal leakage could occur at impact speeds as low as 97 kilometers (60 miles) per hour. At the proposed repository, the casks would be lifted a maximum of 7.1 meters (23 feet) according to the Draft EIS, Volume II, Appendix H, p. H-4. A drop from this distance would produce an impact velocity of 42

Table H-1. Internal-event-initiated accidents evaluated for further analysis.[a]

No.	Location[b]	Accident[c]	MAR[d] (PWR SFAs)	Frequency (events/year)	EIS disposition
A. Category 1 Accidents (DIRS 155734-DOE 2001, Table 5-5)					
1-01	P	SFA drop on SFA	2	0.2	Bounded by 1-07[e]
1-02	P	SFA collision	1	0.04	Bounded by 1-07
1-03	P	SFA drop on empty basket	1	0.04	Bounded by 1-07
1-04	P	SFA drop on SFA in rack	2	0.2	Bounded by 1-07
1-05	P	Basket drop onto basket in rack	8	0.04	Bounded by 1-07
1-06	P	Basket drop onto basket in storage (transfer into pool storage)	8	0.04	Same as 1-07
1-07	P	Basket drop onto basket in pool (transfer out of pool storage)	8	0.04	Retained
1-08	P	Basket drop onto transfer cart/floor (transfer out of pool storage)	4	0.04	Bounded by 1-07
1-09	P	Basket drop into pool	4	0.04	Bounded by 1-07
1-10	C	Basket drop onto cell floor	4	0.04	Bounded by 1-11
1-11	C	Basket drop onto basket in dryer	8	0.04	Retained
1-12	C	SFA drop on another SFA in dryer	2	0.2	Bounded by 1-11
1-13	C	SFA drop on cell floor	1	0.2	Bounded by 1-11
1-14	C	SFA drop on SFA in DC	2	0.2	Bounded by 1-11
B. Category 2 Accidents (DIRS 155734-DOE 2001, Table 5-6)					
2-01	P	Basket collision during transfer	4	0.007	Bounded by 1-07
2-02	P	Uncontrolled descent of transfer cart	4	0.007	Bounded by 1-07
2-03	P	Handling equipment drop on basket	4	0.002	Bounded by 1-07
2-04	C	Handling equipment drop on basket	4	0.00007	Bounded by 1-11
2-05	D	Unsealed DC collision	21	0.002	Bounded by 2-06
2-06	D	Unsealed DC drop	21	0.008	Retained
2-07	D	Handling equipment drop on DC	21	0.0001	Bounded by 2-06
2-08	C	Unsealed shipping cask drop	26	0.009	Retained
2-09	P	Unsealed shipping cask drop	26	0.009	Retained

C. Accidents evaluated in Draft EIS

Event	Location	Accident	MAR[d]	Filters	Frequency	Disposition
1	A	6.9-meter drop of shipping cask	61 BWR	No	0.00045	Eliminated
3	A	7.1-meter drop of shipping cask	26 PWR	No	0.00061	Eliminated
5	A	4.1-meter drop of shipping cask	61 BWR	No	0.0014	Eliminated
7	A	4.1-meter drop of shipping cask	26 PWR	No	0.0019	Eliminated
9	B	6.3-meter drop of multicanister overpack	N-Reactor fuel	Yes	0.00045	Eliminated
10	B	6.3-meter drop of multicanister overpack	N-Reactor fuel	No	0.00000022	Eliminated
11	C	5-meter drop of transfer basket (onto another basket)	8 PWR	Yes	0.011	Retained (same as 1-11)
12	C	5-meter drop of transfer basket (onto another basket)	8 PWR	No	0.00000028	Eliminated
13	C	7.6-meter drop of transfer basket (onto another basket)	16 BWR	Yes	0.0074	Retained
14	C	7.6-meter drop of transfer basket (onto another basket)	16 BWR	No	0.00000019	Eliminated
15	D	6-meter vertical drop of DC	21 PWR	Yes	0.0018	Retained (same as 2-06)
16	D	6-meter vertical drop of DC	21 PWR	No	0.00000086	Eliminated
19	E	Transporter runaway and derailment	21 PWR	Yes	0.00000012	Retained (without filters)

a. Source: Modified from DIRS 147496-CRWMS M&O (2000, pp. 5-21 and 5-22).
b. Location designators: A = Cask/Carrier Transport and Handling Area; B = Canister Transfer System; C = Assembly Transfer System Spent Fuel Handling; D = Disposal Container Handling System; E = Waste Emplacement and Subsurface Facility; P = Assembly Transfer System or Blending Inventory Pool.
c. To convert meters to feet, multiply by 3.2808.
d. MAR = material at risk; SFA = spent fuel assembly, BWR = boiling-water reactor, PWR = pressurized-water reactor, DC = disposal container.
e. Bounding is based on the highest material at risk independent of event frequency.

kilometers (26 miles) per hour (see Section H.2.1.4.2). Thus, shipping cask seal leakage would be unlikely from an accidental drop from the maximum lift heights during cask handling operations. This conclusion is consistent with DIRS 147496-CRWMS M&O (2000, all) because no accidents were identified in the Cask/Carrier Transport and Handling Area with the potential to release radioactive materials. Therefore, DOE eliminated accidents 1, 3, 5, and 7 from further consideration, as indicated in the EIS disposition column of Table H-1.

H.2.1.1.2 *Canister Transfer System*

Some spent nuclear fuel and high-level radioactive waste would arrive at the repository in canisters suitable for direct placement in disposal containers. The canister transfer system would unload these canisters from a transportation cask and load them in a disposal container in the Waste Handling Building confinement system. This system would include a filtration function that would ensure that any radioactive material that could be released would pass through high-efficiency particulate air filters before exhausting to the atmosphere. During these operations, canister drops could release radioactive material. Accident evaluations performed for the Draft EIS, Volume II, Appendix H, p. H-5 determined that the drop of a canister containing N-Reactor fuel could produce a radioactive release, and that this accident would bound other accidents involving canisters. Two such accidents, Numbers 9 and 10 as listed in Table H-1, were considered. However, since the publication of the Draft EIS, DOE has established waste acceptance criteria that specify (DIRS 110306-DOE 1999, p. 20) that waste canisters arriving at the proposed repository for emplacement (1) withstand drops from the maximum lift height during repository handling operations without a release, or (2) if a drop would result in a release, ensure that resulting doses would be within requirements established by the Nuclear Regulatory Commission assuming no filtration of released radionuclides by the Waste Handling Building ventilation system. As a result of these requirements, DOE did not evaluate impacts from canister drops. However, a drop of a defective canister could produce a release. The probability that a canister could be manufactured with a defect significant enough to produce a failure if dropped has been conservatively estimated to be 3×10^{-6} per canister (DIRS 154327-DOE 2000, p. 1). To determine the annual probability of a release, it is necessary to combine the number of canister lift operations per year with the probability of a drop and the probability of a defective canister. The estimated maximum number of DOE canister lifts per year would be 2,114 (DIRS 152151-CRWMS M&O 2000, p. 2-3), and the estimated probability of a drop per lift would be 1.4×10^{-5} (DIRS 103237-CRWMS M&O 1998, p. 14). Thus, the probability of a release involving a drop of a defective canister is:

2,114 canister lifts per year (maximum) $\times 1.4 \times 10^{-5}$ canister drops per year $\times 10^{-6}$ defect per canister = 8.9×10^{-8} releases per year.

This probability is below the credibility limit established by DOE for environmental impact assessment (DIRS 104601-DOE 1993, p. 28) of once in 10 million years (1×10^{-7} per year). Therefore, DOE did not evaluate this accident scenario further.

H.2.1.1.3 *Assembly Transfer System*

The Assembly Transfer System would handle bare, intact commercial spent nuclear fuel assemblies from pressurized- and boiling-water reactors. The assemblies would be unloaded from the transportation casks in the cask unloading pool. Next, they would be moved to the assembly holding pool or the fuel blending inventory pools where they would be placed in baskets that contained either four pressurized-water reactor assemblies or eight boiling-water assemblies. The baskets would be moved from the pool and transferred to the assembly drying station from which they would be loaded, after drying, in the disposal containers. In the cask preparation pit of the assembly transfer system, the lid would be removed from the shipping cask and the cask would be transferred to the cask unloading pool. During transfer of the shipping cask from the pit to the pool, the cask could be accidentally dropped onto the cask preparation pit floor or the transfer pool floor (DIRS 147496-CRWMS M&O 2000, p. 5-24). These accidents are listed as 2-08 and 2-09 in Table H-1. However, the number of fuel assemblies has been reduced from 26 to 24 for this accident. The 26 pressurized-water reactor fuel assembly case was selected for the preclosure safety assessment (DIRS 147496-CRWMS M&O 2000, p. 5-24) to represent an upper limit on the number of pressurized-water reactor fuel assemblies in a rail transportation cask. The most probable number of pressurized-water reactor assemblies in a rail transportation cask is 24, as discussed in Appendix J, Section J.1.4.2. The estimated frequency of these accidents would be 0.0087 per year (DIRS 147496-CRWMS M&O 2000, p. 5-22), based on the number of unsealed shipping cask handling operations expected at the proposed repository and the failure probability of the shipping cask handling crane (DIRS 150276-CRWMS M&O 2000, Attachment VII, pp. VII-1 through VII-20).

The cask preparation pit and unloading pool would be in the Waste Handling Building confinement system. This system would include a filtration function that would ensure that any radioactive material that could be released would pass through high-efficiency particulate air filters before exhausting to the atmosphere. Thus, for these two unsealed shipping cask drop accidents, any radioactive material released from the cask would be filtered by the Waste Handling Building confinement system before being released to the environment. For this EIS, DOE examined the probability of failure of the confinement filtration system in conjunction with these accidents. The filtration system failure probability for a 24-hour period would be 1.7×10^{-7} (DIRS 137064-CRWMS M&O 1999, all). Thus, the probability of filtration system failure in conjunction with an unsealed shipping cask drop would be 8.7×10^{-3} multiplied by $1.7 \times 10^{-7} = 1.5 \times 10^{-9}$ per year. This probability is well below the credibility limit established by DOE (DIRS 104601-DOE 1993, p. 28) of once in 10 million years (1×10^{-7} per year). Therefore, DOE did not evaluate this accident scenario further.

After the shipping casks were placed in the pool with lids removed, the spent fuel assemblies (either bare or canistered assemblies) would be removed and placed in storage racks or in transfer baskets. The transfer baskets could contain either four pressurized-water reactor assemblies or eight boiling-water reactor assemblies. A loaded transfer basket would be loaded into the transfer cart. All of these operations would take place underwater in the 15-meter- (50-foot)-deep pool. DOE evaluated accidental drops of individual spent fuel assemblies or of transfer baskets during these operations. Accidents involving these underwater operations are listed in Table H-1 as accidents 1-01 through 1-09 and 2-01 through 2-03, and 11 through 14. In examining these accidents, DOE determined that accident 1-06 or 1-07 would produce the maximum radiological impacts because the amount of radioactive material released would be directly proportional to the amount of spent nuclear fuel involved in the accident (MAR column in Table H-1). Therefore, DOE retained only accident 1-07 for further evaluation in the EIS, as indicated in the EIS disposition column in Table H-1. This accident, based on assumptions in Section H.2.1.4, would produce the maximum consequences (impacts) for all fuel-handling accidents in the pool and, therefore, would bound accidents 1-01 through 1-06. Furthermore, this accident would bound accidents 2-01, 2-02, and 2-03 because more material at risk would be involved in 1-07.

The next accidents considered in Table H-1 involve events that could occur after the spent fuel assemblies were removed from the pool and prepared for disposal container loading. Spent fuel assemblies would be brought to the assembly transfer system hot cell from the pool for drying by the transfer cart, which would hold one transfer basket. After the cart arrived in the cell, the basket would be lifted out of the cart and placed in the dryer. After drying, the assemblies would be lifted out of the dryer vessel and placed in the disposal container in the hot cell. During these operations, assemblies could be dropped to the hot cell floor, into the dryer, or into the disposal container. These accidents are listed in Table H-1 as events 1-10 through 1-14, 2-04, and 11 through 14. Because these accidents would occur in the Waste Handling Building confinement system, radioactive releases would be filtered by the confinement filtration system. As noted above, a recent assessment (DIRS 137064-CRWMS M&O 1999, all) estimated that the filtration

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system failure probability has been reduced to 1.7×10^{-7}. Thus, neither accident involving filter system failure in conjunction with a transfer basket drop (accidents 12 and 14) would be credible (probability of greater than once in 10 million years or 1×10^{-6} per year). Accident 12 would have a probability of $1.1 \times 10^{-2} \times 1.7 \times 10^{-7}$ or 1.9×10^{-9} per year and accident 14 would have a probability of $7.4 \times 10^{-3} \times 1.7 \times 10^{-7}$ or 1.3×10^{-9} per year. The remaining accidents would be bounded by accident 1-11, which would involve the highest radionuclide inventory (material at risk) and thus would provide the largest source term and impacts.

H.2.1.1.4 *Disposal Container Handling System*

The Disposal Container Handling System would prepare empty disposal containers for the loading of nuclear materials, transfer disposal containers to and from the assembly and canister transfer systems, weld the inner and outer lids of the disposal containers, and load disposal containers on the waste emplacement transporter. DOE examined the details of these operations and identified several accidents that could occur. These are accidents 2-05, 2-06, 2-07, and 15 and 16 in Table H-1. The first three accidents are bounded by accident 2-06 because this event would impart the most energy to the material at risk (21 pressurized-water reactor fuel assemblies) and thus would result in the most fuel damage leading to the highest release of radioactive material (see Section H.2.1.4). Accident 15 is the same as accident 2-06, and DOE eliminated accident 16 because the drop of a disposal container concurrent with a failure of the filtration system would be incredible based on a recent evaluation of the failure of the system (DIRS 137064-CRWMS M&O 1999, all) that, as noted above, estimated the failure probability as 1.7×10^{-7} for a 24-hour period. The combined probability in this case is $1.8 \times 10^{-3} \times 1.7 \times 10^{-7}$ or 3.1×10^{-10} per year, well below the credibility level of 1×10^{-7} per year.

H.2.1.1.5 *Waste Emplacement and Subsurface Facility Systems*

The waste emplacement system would transport the loaded and sealed waste package from the Waste Handling Building to the subsurface emplacement area. This system would operate on the surface between the North Portal and the Waste Handling Building, and in the underground ramps, main drifts (tunnels), and emplacement drifts. It would use a shielded transporter car for waste package transportation. The transporter car would be moved into the waste emplacement area by an electric locomotive and the waste package would be placed in the emplacement drift. The only accident in Table H-1 that would involve subsurface emplacement operations is accident 19 from Section C (transporter runaway and derailment). DOE has retained this accident for evaluation but has modified it such that the release would not be filtered. This is because the current design concept (DIRS 153849-DOE 2001, all) does not contain an automatic subsurface filter system (DIRS 150941-CRWMS M&O 2000, p. 4-23), as did the design concept evaluated in the Draft EIS. The design concept does retain filtration capability (DIRS 150941-CRWMS M&O 2000, p. 4-23), but it would be a manual system that might not be available in time to provide filtration of the release from the transporter runaway accident. Final design details of the transporter system have not been established. A recent evaluation of transporter accident potential determined that several design features (five of the six evaluated) could reduce the probability of transporter runaway to less than 0.0000001 per year (DIRS 149105-CRWMS M&O 2000, all). If DOE selected any of these features, the transporter runaway accident retained for analysis in this evaluation could become not credible.

A recent evaluation of potential waste package accidents during emplacement activities considered a comprehensive evaluation of accident initiating events (DIRS 150198-CRWMS M&O 2000, all). This evaluation concluded that either the accident-initiating event would not be credible or would be within the design basis of the waste package. However, one event, a rockfall involving a rock weight of more than 6 metric tons (6.6 tons) (assumed to be large enough to fail the waste package), would have a probability of 5×10^{-7} per year. While this event would not be credible under Nuclear Regulatory

Commission safety regulations (DIRS 147496-CRWMS M&O 2000, p. 4-18), it would be credible based on DOE guidelines for environmental impact analysis (DIRS 104601-DOE 1993, p. 28) and, therefore, the Department evaluated it further. The evaluation of a failure of a waste package after emplacement (DIRS 150276-CRWMS M&O 2000, all) assumed that the waste package would fail from unspecified causes and that all of the pressurized-water reactor fuel rods in 21 fuel assemblies would rupture and release all radioactive gases in them. The calculated site boundary dose from this event would be 0.0027 rem (DIRS 150276-CRWMS M&O 2000, p. X-48). As discussed in Section H.2.1.5, this dose would be far less than that produced from the transporter runaway and derailment accident, which would damage the waste package being transported for emplacement. Therefore, the rockfall on a waste package event is bounded by the transporter runaway accident, and is not evaluated further.

H.2.1.2 Internal Events – Waste Treatment Building

An additional source of radionuclides could be involved in accidents in the Waste Treatment Building. This building, which would be connected to the northeast end of the Waste Handling Building, would house the Site-Generated Radiological Waste Handling System (DIRS 104508-CRWMS M&O 1999, p. 37). This system would collect site-generated low-level radioactive solid and liquid wastes and prepare them for disposal. The radioactivity of the waste streams would be low enough that no special features would be required to meet Nuclear Regulatory Commission radiation safety requirements (shielding and criticality) (DIRS 104508-CRWMS M&O 1999, p. 42).

The liquid waste stream to the Waste Treatment Building would consist of aqueous solutions that could contain radionuclides resulting from decontamination and washdown activities in the Waste Handling Building. The liquid waste would be evaporated, mixed with cement (grouted), and placed in 0.21-cubic-meter (55-gallon) drums for shipment off the site (DIRS 104508-CRWMS M&O 1999, p. 55). The evaporation process would reduce the volume of the liquid waste stream by 90 percent (DIRS 101816-DOE 1997, Summary).

The solid waste would consist of noncompactible and compactible materials and spent ion-exchange resins. These materials ultimately would be encapsulated in concrete in 0.21-cubic meter (55-gallon) drums after appropriate processing (DIRS 104508-CRWMS M&O 1999, p. 55).

Water in the Assembly Staging Pools of the Waste Handling Building would pass through ion exchange columns to remove radionuclides and other contaminants. These columns would accumulate radionuclides on the resin in the columns. When the resin is spent (unable to remove radionuclides effectively from the water), the water flow would be diverted to another set of columns, and the spent resin would be removed and dewatered for disposal as low-level waste or low-level mixed waste. These columns could have external radiation dose rates associated with them because of the activation and fission product radionuclides accumulated on the resins. They would be handled remotely or semiremotely. During the removal of the resin and preparation for offsite shipment in the Waste Treatment Building, an accident scenario involving a resin spill could occur. However, because the radionuclides would have been chemically bound to the resin in the column, an airborne radionuclide release would be unlikely. Containment and filter systems in the Waste Treatment Building would prevent exposure to the public or noninvolved workers. Some slight exposure of involved workers could occur during the event or during recovery operations afterward. DOE made no further analysis of this event.

Because there is no detailed design of the Waste Treatment Building at present and operational details are not yet available, DOE used the recent Waste Management Programmatic EIS (DIRS 101816-DOE 1997, all) and supporting documentation (DIRS 103688-Mueller et al. 1996, all) to aid in identifying potential accident scenarios and evaluating radionuclide source terms. DOE based the information in the Waste

Management Programmatic EIS on high- and low-level waste handling and treatment experience at various sites. At those sites, DOE has stored, packaged, treated, and transported these wastes for several decades and has compiled an extensive database of information relevant to accident assessments (for example, safety analysis reports, unusual occurrences). For radiological impacts, the analysis focused on accident scenarios with the potential for airborne releases to the atmosphere. The liquid stream can be eliminated because it has a very low potential for airborne release; the radionuclides would be dissolved and energy sources would not be available to disperse large amounts of the liquid into droplets small enough to remain airborne. Many low-level waste treatment operations, including evaporation, solidifying (grouting), packaging, and compaction can be excluded because they would lack sufficient mechanistic stresses and energies to create large airborne releases, and nuclear criticalities would not be credible for low-level waste (DIRS 103688-Mueller et al. 1996, p. 13). Drum-handling accidents are expected to dominate the risk of exposure to workers (DIRS 103688-Mueller et al. 1996, p. 93).

The estimated frequency of an accident involving drum failure is about 0.0001 failure per drum operation (DIRS 103688-Mueller et al. 1996, p. 39). The total number of drums containing grouted aqueous waste would be 2,280 per year (DIRS 100248-CRWMS M&O 1997, p. 30). The analysis assumed that each drum would be handled twice, once from the Waste Treatment Building to the loading area, and once to load the drum for offsite transportation. Therefore, the frequency of a drum failure involving grouted aqueous waste would be:

Frequency = 2,280 aqueous (grouted) low-level waste drums per year
× 2 handling operations per drum
× 0.0001 failure per handling operation
= 0.46 aqueous (grouted) low-level waste drum failures per year.

The number of solid-waste grouted drums produced would be 2,930 per year (DIRS 100248-CRWMS M&O 1997, p. 35). Assuming two handling operations and the same failure rate yields a frequency of drum failure of:

Frequency = 2,930 solid low-level waste drums per year
× 2 handling operations per drum
× 0.0001 failure per handling operation
= 0.59 solid low-level waste drum failures per year.

Failure of these drums would result in a release of radioactive material, which later sections (H.2.1.4.5, H.2.1.5) evaluate further.

H.2.1.3 External Events

External events are either external to the repository (earthquakes, high winds, etc.) or are natural processes that occur over a long period of time (corrosion, erosion, etc.). DOE performed an evaluation to identify which of these events could initiate accidents at the repository with potential for release of radioactive material.

Because some external events evaluated as potential accident-initiating events would affect both the Waste Treatment and Waste Handling Buildings simultaneously [the buildings are physically connected (DIRS 104508-CRWMS M&O 1999, Attachment IV, Figure 6)], this section considers potential accidents involving external event initiators, as appropriate, for the combined buildings.

Table H-2 lists generic external events developed as potential accident initiators for consideration at the proposed repository and indicates how each potential event could relate to repository operations based on an initial evaluation process. The list, from (DIRS 100204-CRWMS M&O 1996, p. 15), was developed by an extensive review of relevant sources and known or predicted geologic, seismologic, hydrologic, and

Table H-2. External events evaluated as potential accident initiators.[a]

Event	Relation to repository[b]	Comment
Aircraft crash	A	
Avalanche	C	
Coastal erosion	B	
Dam failure	C	
Debris avalanche	A	Caused by excessive rainfall
Dissolution	A	Chemical weathering of rock
Epeirogenic displacement (tilting of the Earth's crust)	D (earthquake)	Large-scale surface uplifting and subsidence
Erosion	D (flooding)	
Extreme wind	A	
Extreme weather	A	Includes extreme episodes of fog, frost, hail, ice cover, etc.
Fire (range)	A	
Flooding	A	
Denudation	E	Wearing away of ground surface by weathering
Fungus, bacteria, algae	E	A potential waste package long-term corrosion process not relevant during the repository operational period[c]
Glacial erosion	B	
High lake level	C	
High tide	B	
High river stage	C	
Hurricane	B	
Inadvertent future intrusion	E	To be addressed in postclosure Performance Assessment
Industrial activity	A	
Intentional future intrusion	E	
Lightning	A	
Loss of offsite or onsite power	A	
Low lake level	C	
Meteorite impact	A	
Military activity	A	
Orogenic diastrophism	D (earthquake)	Movement of Earth's crust by tectonic processes
Pipeline rupture	C	
Rainstorm	D (flooding)	
Sandstorm	A	
Sedimentation	B	
Seiche	B	Surface water waves in lakes, bays, or harbors
Seismic activity, uplift	D (earthquake)	
Seismic activity, earthquake	A	
Seismic activity, surface fault	D (earthquake)	
Seismic activity, subsurface fault	D (earthquake)	
Static fracture	D (earthquake)	Rock breakup caused by stress
Stream erosion	B	
Subsidence	D (earthquake)	Sinking of Earth's surface
Tornado	A	
Tsunami	B	Sea wave caused by ocean floor disturbance
Undetected past intrusions	E	
Undetected geologic features	D (earthquake, volcanism ash fall)	
Undetected geologic processes	D (erosion, earthquake, volcanism ash fall)	
Volcanic eruption	D (volcanism ash fall)	
Volcanism, magmatic	D (volcanism ash fall)	
Volcanism, ash flow	D (volcanism ash fall)	
Volcanism, ash fall	A	
Waves (aquatic)	B	

a. Source: DIRS 146897-CRWMS M&O (2000, Table 6-1).
b. A = retained for further evaluation; B = not applicable because of site location; C = not applicable because of site characteristics (threat of event does not exist in the vicinity of the site); D = included in another event as noted; E = does not represent an accident-initiating event for proposed repository operations.
c. Source: DIRS 146897-CRWMS M&O (2000, p. 31).

other characteristics. The list includes external events from natural phenomena as well as man-caused events.

The center column in Table H-2 (relation to repository) represents the results of an evaluation to determine the applicability of the event to the repository operations, and is based in part on evaluations previously reported in (DIRS 100204-CRWMS M&O 1996, all; DIRS 147496-CRWMS M&O 2000, Section 5; DIRS 104508-CRWMS M&O 1999, all). Events were excluded for the following reasons:

- Not applicable because of site location (condition does not exist at the site)
- Not applicable because of site characteristics (potential initiator does not exist in the vicinity of the site)
- Included in another event
- Does not represent an accident-initiating event for proposed repository operations

The second column of Table H-2 identifies the events excluded for these reasons. The preliminary evaluation retained the events identified in Table H-2 with "A" for further detailed evaluation. The results of this evaluation are as follows:

1. Aircraft Crash. This assessment evaluated the probability of an aircraft crash on the proposed Yucca Mountain Repository to see if such an event would be reasonably foreseeable and, therefore, a candidate for consequence analysis. Since the publication of the Draft EIS, new information and data have become available. The information and data include the following:

   a. The design concept of the Waste Handling Building has been updated. The flexible design concept includes thinner walls in the upper regions of the building, as well as a smaller footprint for areas of the building where the waste would be out of the storage pools. As a consequence, the target area for the aircraft impact has changed.

   b. A recent assessment of aircraft crash probability contains information useful for the reassessment (DIRS 154930-NRC 2000, all).

   c. Since March 1999, DOE has collected aircraft overflight data to evaluate the frequency of overflights in the region of the repository. Because this information was not available for the Draft EIS, that evaluation assumed a constant overflight density in the entire flight corridor [49 kilometers (30 miles)] that encompasses the repository. The overflight data indicate that the flight density over the repository site is less than the average for the flight corridor. (The repository site is at the extreme western edge of the flight corridor.) DOE used this recent overflight data in the assessment.

   d. The repository design could include a surface aging facility, which DOE is considering as an option to enable aging of commercial nuclear fuel prior to emplacement. The aging process would reduce the heat generation rate from spent nuclear fuel. Thus, aging could be used to control subsurface temperatures. DOE evaluated the aircraft crash probability and consequences for this facility.

   Aircraft Overflights. As noted in the Draft EIS (Appendix H, page H-10), the only aircraft that fly over the repository airspace are military aircraft from Nellis Air Force Base. This conclusion is also derived in a recent aircraft crash probability analysis (DIRS 108290-CRWMS M&O 1999, Section 7.1). The only information available on the frequency of military overflights at the time of the Draft EIS analysis was the total number of flights in the 47-kilometer- (29-mile)-wide flight corridor used by Nellis Air Force Base, which includes the repository at its western edge. The Draft EIS used the Uniform Overflight Density Model to estimate the frequency of aircraft crashes on the site. However, in March 1999, DOE began actual counting of aircraft overflying a 10-kilometer- (6-mile)-wide airway with the repository at the center. To date, overflight data have been processed on a quarterly basis. The results through June 30, 2001, are as follows (DIRS 155256-Morissette 2001, all; DIRS 155257-Morissette 2001, all; DIRS 156117-Morissette 2001, all; DIRS 154768-Monette 2001, all):

Fiscal year	Quarter	Number of overflights
1999	Third	361
1999	Fourth	274
2000	First	424
2000	Second	328
2000	Third	648
2000	Fourth	326
2001	First	490
2001	Second	370
2001	Third	769

The average number of quarterly overflights from these data was 443, giving an annual average of 1,773. This value is less than the number of flights that would be expected in the 10-kilometer- (6-mile)-wide airway if the 13,000 flights per year used in the Draft EIS were evenly distributed over the 49-kilometer- (30-mile)-wide corridor (13,000/30 × 6 = 2,690). In other words, actual flightpaths are concentrated east of the repository. In the Draft EIS assessment, DOE used the Uniform Overflight Density Model because site-specific overflight information was not available. However, because repository-specific overflight data are now available, DOE decided to use the Nuclear Regulatory Commission Airway Model in the reassessment. This model was also used in DIRS 108290-CRWMS M&O (1999, p. 26), which noted that it gives somewhat higher crash estimates than the Uniform Overflight Density Model when applied to the 49-kilometer-wide corridor case. Therefore, the results in this appendix are conservative based on the selection of the model.

DOE also examined the potential for a change in overflight numbers at the time of repository operation due to aircraft operational changes contemplated by the Air Force. The only known planned change in future activities involves the addition of F-22 fighter aircraft at Nellis Air Force Base. The additional aircraft would increase flight activities by 2 to 3 percent over current activities (DIRS 104707-Myers 1997, p. 3).

Commercial air traffic is not allowed in the air space over the proposed repository location. An inadvertent commercial flight over the restricted repository air space followed by a crash into the repository would be significantly less probable than the military crash probability evaluated in this analysis.

Airway Model. The Airway Model from NUREG-0800 (DIRS 152082-NRC 1981, Section 3.5.1.6, p. 3.5.1.6-3) is:

$$P_{FA} = C \times N \times A/w$$

where:

P_{FA} is the probability per year of the aircraft crashing into the facility

C is the crash rate in crashes per mile flown
N is the number of flights per year along the airway
A is the effective area of the facility (square miles)
w is the width of the airway (miles).

This model was used by the analysis in the *Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band Indians and the Related Transportation Facility in Tooele County, Utah* (DIRS 152001-NRC 2000, all), and was modified to account for the fact that Air Force fighter pilots would be likely to attempt to direct aircraft away from ground structures before ejecting if they could maintain flight control. The Nuclear Regulatory Commission accepted this modification (DIRS 154930-NRC 2000, p. 198). DOE considered this modification to be applicable to the repository crash analysis based on similar conditions, including overflights in high-altitude cruise mode, similar pilot training, and similar aircraft. The modification consisted of separating the crash probability into two components, P_1 and P_2, where the overall crash probability P_{FA} is the sum of P_1 and P_2. The P_1 component represents the probability of an aircraft crashing on the repository as a result of engine failure or other malfunction with the pilot retaining control of the aircraft. P_2 is the probability of an aircraft crashing on the repository due to engine failure or other malfunction with the pilot not retaining control of the aircraft. The analysis then reformulated the overall crash probability as follows:

$$P_{FA} = P_1 + P_2 = C \times N \times A/w \times R_1 + C \times N \times A/w \times R_2$$

where:

R_1 = probability that the crash is of the type such that the pilot retains control of the aircraft but is unable to guide the aircraft away from repository structures. This is the product of the probability that the pilot retains control of the aircraft for a time that is sufficient to guide the aircraft away from the facility (0.9) and the probability that the pilot will still not be able to guide the aircraft away from the structures (0.05). The assessment estimated the value of R_1 at 0.045 (DIRS 154930-NRC 2000, p. 197) based on crash data, pilot training and experience, and other factors.

R_2 = probability that the crash is of the type such that the pilot does not retain control of the aircraft and is, therefore, unable to guide the aircraft away from the repository before ejecting. The assessment estimated the value of R_2 as 0.1 (DIRS 154930-NRC 2000, p. 197). This value is based on crash data which indicate that a pilot would retain control of the aircraft with sufficient time to steer the plane away from surface structures for 90 percent of F-16 crashes (DIRS 154930-NRC 2000, p. 197).

Based on these considerations, the overall crash rate becomes:

$$P_{FA} = C \times N \times A/w \times (0.045) + C \times N \times A/w \times (0.1) = C \times N \times A/w \times (0.145).$$

Using this formula, DOE evaluated the crash rate for both the Waste Handling Building and a surface aging facility.

Crash Rate (C). The aircraft operating out of Nellis Air Force Base consist of more than 20 different types (DIRS 103472-USAF 1999, p. 1-35). However, the predominant aircraft types are F-16, F-15, and A-10 jets. These three types represent more than 75 percent of all aircraft operating out of Nellis, with the F-16 aircraft being the most prevalent, representing almost half (46 percent) of all aircraft operations (DIRS 103472-USAF 1999, pp. 1-35, 1-36). Estimates of the crash rates for these three aircraft are as follows (DIRS 108290-CRWMS M&O 1999, p. 18):

Aircraft	Crash rate/mile
F-16	3.86×10^{-8}
F-15	6.25×10^{-9}
A-10	3.14×10^{-8}

This analysis selected the F-16 crash rate to represent all aircraft operating out of Nellis Air Force Base. This selection was based on the fact that the F-16 aircraft, as noted, is the most numerous aircraft involved in Nellis operations, and it has the highest crash rate of the three most predominant aircraft and, therefore, results in a conservative evaluation. The rate is also somewhat conservative compared to a recent aircraft crash evaluation performed for the proposed Private Fuel Storage Facility in Utah (DIRS 154930-NRC 2000, Section 1.5.1.2.11). That analysis used an F-16 crash rate of 2.74×10^{-8} (DIRS 154930-NRC 2000, p. 193).

Effective Area of the Repository. According to the Nuclear Regulatory Commission (DIRS 152082-NRC 1981, p. 3.5.1.6-5), the effective area, A, to be used in the model should include the shadow area, the skid area, and the plant area. However, the equations for calculating these areas are not provided. Both DIRS 108290-CRWMS M&O (1999, p. 22) and DIRS 103687-Kimura, Sanzo, and Sharirli (1998, p. 9) use the formula recommended by DOE (DIRS 101810-DOE 1996, all). This formula is:

$$A = A_f + A_s$$

where

A_f is the effective fly-in area
A_s is the effective skid area.

Further,

$$A_f = \left[(Ws + R) \times H\cot\Phi\right] + \left[\frac{2L \times W \times Ws}{R}\right] + L \times W$$

$$A_s = (R+Ws)S$$

where

Ws	=	aircraft wingspan
H	=	facility height (feet)
$\cot\Phi$	=	mean of the cotangent of the aircraft impact angle
L	=	length of the facility (feet)
W	=	width of the facility (feet)
S	=	aircraft skid distance (feet)
R	=	length of the diagonal of the facility = $(L^2 + W^2)^{1/2}$.

The value of $\cot\Phi$ is 8.4 for in-flight crashes for small military aircraft (DIRS 101810-DOE 1996, p. B-29). The skid area is based on a skid distance (S). The analysis used a skid distance of 75 meters (246 feet) for small military aircraft under in-flight crash conditions based on mishap reports (DIRS 101810-DOE 1996, p. B-29). The wingspan recommended for high-performance jet fighters is 24 meters (78 feet) (DIRS 101810-DOE 1996, p. B-28). The remaining parameters (W, L, R, and H) are target (facility) specific.

- Waste Handling Building. The width of the Waste Handling Building would be about 116 meters (380 feet) (DIRS 152010-CRWMS M&O 2000, Figure 9, p. IV-11). This width includes all areas where spent nuclear fuel assemblies and high-level radioactive waste would be handled out of the storage pools. The spent nuclear fuel in the storage pools would not be vulnerable because it would be covered with 15 meters (50 feet) of water (DIRS 152010-CRWMS M&O 2000, Figure 13, p. IV-15). Even if the aircraft penetrated the walls around the pools, sank into the pool, and damaged the fuel, the release would be minimal because the pool water would retain most radionuclides (DIRS 150276-CRWMS M&O 2000, p. 20). Because the storage pool areas would be below grade, the aircraft could not enter the side of the pool and cause drainage in conjunction with spent nuclear fuel damage.

  The estimated length (L) of the facility vulnerable to aircrash impact would be 165 meters (542 feet) (DIRS 152010-CRWMS M&O 2000, Figure 9, p. IV-11).

  The length and width values include the disposal container transporter loading areas and handling cells for both the assembly and canister transfer systems. They also include the assembly dryer cells, the canister transfer cells, and the shipping cask preparation and transfer areas. The values for length and width are conservative because they encompass areas that are not vulnerable to radioactive release from air crashes, such as the heating, ventilation, and air conditioning areas, electrical equipment room, and hallways and corridors.

  The height of the facility would be 22 meters (73 feet) (DIRS 152010-CRWMS M&O 2000, Figure 13, p. IV-15). This would encompass the areas where radioactive material would be handled.

  The effective area, A, then becomes (in square feet):

$$A = \left[(Ws + R) \times H\cot\Phi\right] + \left[\frac{2L \times W \times Ws}{R}\right] + L \times W + (R + Ws)S$$

$$A = \left\{78 + \left[(542)^2 + (380)^2\right]^{1/2}\right\} \times (73)(8.40) + \left\{(2)542 \times 380 \times 78/\left[(542)^2 + (380)^2\right]^{1/2}\right\} + 542 \times 380 + \left[\left\{(542)^2 + (380)^2\right\}^{1/2} + Ws\right]S$$

$$= (78 + 662) \times 613 + 32{,}129{,}760/662 + 205{,}960 + (662 + 78)246$$

$$= 453{,}620 + 48{,}534 + 205{,}960 + 182{,}040 = 890{,}154 \text{ ft.}^2 = 0.032 \text{ mi.}^2$$

  Substituting the derived values into the aircraft crash probability equation yields the following for the annual probability of an aircraft crash on repository structures resulting in the release of radioactive material:

$$P_{FA} = C \times N \times A/w \times 0.145 = 3.86 \times 10^{-8} \times 1{,}773 \times 0.032/6 \times 0.145 = 5.2 \times 10^{-8}$$

  This probability is below once in 10 million (1×10^{-7}) per year, which is the probability level DOE has established (DIRS 104601-DOE 1993, p. 28) for consideration of accidents. Although the probability of this accident is outside the range normally presented in DOE EISs. DOE has chosen to present the potential consequences in Section H.2.1.5.1.

- Surface Aging Facility. Using an analysis consistent with the evaluation of the probability of a military aircraft crash into the Waste Handling Building, DOE evaluated the probability of a

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crash on the surface aging facility. The effective area of this facility, based on dimensions contained in DIRS 155043-CRWMS M&O (2001, all) was determined to be 0.49 square kilometer (0.19 square mile). Thus, the probability of an aircraft crash on the surface aging facility would be:

$$P_{FA} \quad = \quad C \times N \times A/w \times 0.145 = 3.86 \times 10^{-8} \times 1{,}773 \times 0.19/6 \times 0.145 = 3.14 \times 10^{-7}/\text{yr}.$$

The probability is slightly above the level that DOE has used in previous EISs. Section H.2.1.3.1 discusses the results of this analysis.

2. **Debris Avalanche.** This event, which can result from persistent rainfall, would involve the sudden and rapid movement of soil and rock down a steep slope. The nearest avalanche potential to the proposed location for the Waste Handling Building is Exile Hill (the location of the North Portal entrance). The base of Exile Hill is about 90 meters (300 feet) from the location of the Waste Handling Building. Since Exile Hill is only about 30 meters (100 feet) high (DIRS 103813-DOE 1997, p. 5.09), it would be unlikely that avalanche debris would reach the Waste Handling Building. Furthermore, the design for the Waste Handling Building includes concrete walls about 1.5 meters (5 feet) thick (DIRS 152010-CRWMS M&O 2000, p. 30) that would provide considerable resistance to an impact or buildup of avalanche debris.

3. **Dissolution.** Chemical weathering could cause mineral and rock material to pass into solution. This process, called dissolution, has been identified as potentially applicable to Yucca Mountain (DIRS 100204-CRWMS M&O 1996, p. 18). However, this is a very slow process, which would not represent an accident-initiating event during the preclosure period being considered in this appendix.

4. **Extreme Wind.** Extreme wind conditions could cause transporter derailment (DIRS 102702-CRWMS M&O 1997, p. 72), the consequences of which would be bounded by a transporter runaway accident scenario. The runaway transporter accident scenario is discussed further in Section H.2.1.4.

5. **Extreme Weather.** This potential initiating event includes various weather-related phenomena including fog, frost, hail, drought, extreme temperatures, rapid thaws, ice cover, snow, etc. None of these events would have the potential to cause damage to the Waste Handling Building that would exceed the projected damage from the earthquake event discussed in this section. In addition, none of these events would compromise the integrity of waste packages exposed on the surface during transport operations. Thus, the earthquake event and other waste package damage accident scenarios considered in this appendix would bound all extreme weather events. It would also be expected that operations would be curtailed if extreme weather conditions were predicted.

6. **Fire.** There would be two potential fire sources external to waste handling areas at the repository site—diesel fuel oil storage tank fires and range fires. Diesel fuel oil storage tanks would be some distance [more than 90 meters (300 feet)] from the Waste Handling Building and Waste Treatment Building (DIRS 104508-CRWMS M&O 1999, Section 4.2). Therefore, a fire at those locations would be highly unlikely to result in any meaningful radiological consequences. Range fires could occur in the vicinity of the site, but would be unlikely to be important accident contributors due to the clearing of land around the repository facilities. Furthermore, the potential for early fire detection and, if necessary, active fire protection measures and curtailment of operations (DIRS 153849-DOE 2001, p. 2-69) would minimize the potential for fire-initiated radiological accidents.

7. **Flooding.** Flash floods could occur in the vicinity of the repository (DIRS 100204-CRWMS M&O 1996, p. 21). However, an earlier assessment (DIRS 103237-CRWMS M&O 1998, p. 32) screened out severe weather events as potential accident-initiating events primarily by assuming that

operational rules will preclude transport and emplacement operations whenever there are local forecasts of severe weather. A quantitative analysis of flood events (DIRS 104699-Jackson et al. 1984, p. 34) concluded that the only radioactive material that extreme flooding would disperse to the environment would be decontamination sludge from the waste treatment complex. The doses resulting from such dispersion would be limited to workers, and would be very small (DIRS 104699-Jackson et al. 1984, p. 53). A more recent study reached a similar conclusion (DIRS 101930-Ma et al. 1992, p. 3-11).

8. **Industrial Activity.** This activity would involve both drift (tunnel) development activities at the repository and offsite activities that could impose hazards on the repository.

   a. Emplacement Drift Development Activities – Drift development would continue during waste package emplacement activities. However, physical barriers in the main drifts would isolate development activities from emplacement activities (DIRS 153849-DOE 2001, Section 2.3.3.3). Thus, events that could occur during drift development activities would be unlikely to affect the integrity of waste packages.

   b. External Industrial Activities – The analysis examined anticipated activities in the vicinity of the proposed repository to determine if accident-initiating events could occur. Two such activities—the Kistler Aerospace activities and the Wahmonie rocket launch facility—could initiate accidents at the repository from rocket impacts. The Wahmonie activities, which involved rocket launches from a location several miles east of the repository site, have ended (DIRS 104722-Wade 1998, all), so this facility poses no risk to the repository. The Kistler Aerospace activities would involve launching rockets from the Nevada Test Site to place satellites in orbit (DIRS 101811-DOE 1996, Volume 1, p. A-42). However, the Kistler Aerospace activity is currently on hold (DIRS 152582-Davis 2000, all), and there is insufficient information to assess if this activity would pose a threat to the repository. If the project moves forward, DOE will evaluate its potential to become an external accident-initiating event. (Aircraft activity is discussed in item 1 above.) No other industrial activities were found that could initiate accidents (DIRS 149759-CRWMS M&O 1999, all).

9. **Lightning.** This event has been identified as a potential design-basis event (DIRS 102702-CRWMS M&O 1997, pp. 86 and 87). Therefore, the analysis assumed that the designs of appropriate repository structures and transport vehicles would include protection against lightning strikes. The lightning strike of principal concern would be the strike of a transporter train during operations between the Waste Handling Building and the North Portal (DIRS 102702-CRWMS M&0 1997, p. 86). The estimated frequency of such an event would be 1.9×10^{-7} per year (DIRS 103237-CRWMS M&O 1998, p. 33). DOE expects to provide lightning protection for the transporter (DIRS 100277-CRWMS M&O 1998, Volume 1, p. 18) such that a lightning strike that resulted in enough damage to cause a release would be well below the credibility level of 1×10^{-7} per year (DIRS 104601-DOE 1993, p. 28).

10. **Loss of Offsite Power.** A preliminary evaluation (DIRS 102702-CRWMS M&O 1997, p. 84) concluded that a radionuclide release from an accident sequence initiated by a loss of offsite power would be unlikely. Loss of offsite power events could result in loss of power to the ventilation system and of the overhead crane system. However, there would be emergency power for safety systems at the site (DIRS 104508-CRWMS M&O 1999, p. 45), and structures, systems, and components important to safety are designed to prevent load drops during loss of offsite power (DIRS 153849-DOE 2001, p. 5-12).

11. Meteorite Impact. The potential for a meteorite strike on the Waste Handling Building was examined and found to be an incredible event. This is based on the following analysis: Small meteorites dissipate their energy in the upper atmosphere and have no direct effect on the ground below. Only when the incoming projectile is larger than about 10 meters (33 feet) in diameter does it begin to pose some hazard to humans. A meteorite in the range of 10 meters in diameter strikes the Earth about once per decade, or a probability of 0.1 per year (DIRS 156370-NASA 2001, Section 2.2). Since the radius of the Earth is 6,383 kilometers (3,963 miles), the surface area of the Earth is 5.11×10^8 square kilometers (2.0×10^9 square miles). Thus, the probability of a hazardous meteorite strike on a specific square kilometer of area is $0.1/5.11 \times 10^8 = 1.96 \times 10^{-9}$ per year. Because the Waste Handling Building design footprint dimensions are (overall outside dimensions, ignoring included open spaces) 214 meters × 181 meters (704 feet × 593 feet) (DIRS 152010-CRWMS M&O 2000, Figure 13, p. IV-15), the target area would be 0.038 square kilometer (0.02 square mile). Therefore, the estimated probability of a hazardous meteor strike is $1.96 \times 10^{-9} \times 0.038 = 7.5 \times 10^{-11}$ per year, well below the credibility threshold of 1×10^{-7} per year (once in 10,000,000 per year) established by DOE (DIRS 104601-DOE 1993, p. 26). For the surface aging facility, the probability would also be below the credibility threshold. This is based on a facility area of 0.49 square kilometer (0.19 square mile) from Item 1 preceding. This area would result in an impact probability of $1.96 \times 0.49 = 9.6 \times 10^{-10}$.

12. Military Activity. Two different military activities would have the potential to affect repository operations. One is the possibility of an aircraft crash from overflights from Nellis Air Force Base. The analysis determined that this event would not be credible, as described above in this section. The second potential activity is the resumption of underground nuclear weapons testing, which the United States has suspended. The only impact such testing could impose on the repository would be ground motion associated with the energy released from the detonation of the weapon. The impact of such motion was the subject of a recent study that concluded that ground motions at Yucca Mountain from nuclear tests would not control seismic design criteria for the potential repository (DIRS 103273-Walck 1996, p. i).

13. Sandstorm. Severe sandstorms could cause transporter derailments and sand buildup on structures. However, such events would be unlikely to initiate accidents with the potential for radiological release. (DIRS 101930-Ma et al. 1992, p. 3-11) reached a similar conclusion. Furthermore, it is assumed that DOE probably would curtail operations if local forecasts indicated the expected onset of high winds with potential to generate sandstorms (DIRS 103237-CRWMS M&O 1998, p. 32). For these reasons, the analysis eliminated this event from further consideration.

14. Seismic Activity, Earthquake ***(including subsidence, surface faults, uplift, subsurface fault, and static fracture).*** DOE has selected the beyond-design-basis earthquake for detailed analysis. The seismic design basis for the repository specifies that structures (including the Waste Handling Building), systems, and components important to safety should be able to withstand the horizontal motion from an earthquake with a return frequency of once in 10,000 years (annual probability of occurrence of 0.0001) (DIRS 103237-CRWMS M&O 1998, p. VII-1). A recent comprehensive evaluation of the seismic hazards associated with the site of the proposed repository (DIRS 100354-USGS 1998, all) concluded that a 0.0001-per-year earthquake would produce peak horizontal accelerations at the site of about 0.53*g* (mean value). Structures, systems, and components are typically designed with large margins over the seismic design basis to account for uncertainties in material properties, energy absorption, damping, and other factors. For nuclear powerplant structures, the methods for seismic design provide a factor of safety of 2.5 to 6 (DIRS 102182-Kennedy and Ravindra 1984, p. R-53). In the absence of detailed design information, the analysis conservatively assumed that the Waste Handling Building would collapse at an acceleration level twice that associated with the design-basis earthquake, or 1.1*g*. Figure H-1 shows that this acceleration level would be likely to occur with a frequency of about 2×10^{-5} per year (mean value).

The Waste Treatment Building is designed to withstand an earthquake event with a return frequency of 1,000 years (annual exceedance probability of 1×10^{-3} per year) (DIRS 104508-CRWMS M&O 1999, p. 14). Consistent with the assumption for the Waste Handling Building, it is assumed that the Waste Treatment Building would collapse during an earthquake that produced twice the design level acceleration. From Figure H-1, the design-basis acceleration for a 1×10^{-3} per year event is 0.18*g*. Thus, the building collapse is assumed to occur at an acceleration level of 0.36, which has an estimated return frequency of about 2×10^{-4} per year. The analysis retains these events as accident initiators, and evaluates the consequences in subsequent sections. The effects of other seismic-related phenomena included under this event (subsidence, surface faults, uplift, etc.) would be unlikely to produce greater consequences than those associated with the acceleration produced by the seismic event selected for analysis (complete collapse of the Waste Handling and Waste Treatment Buildings).

15. **Tornado.** The probability of a tornado striking the repository is estimated to be 3×10^{-7} (three in 10 million) based on an assessment of tornado strike probability for any point on the Nevada Test Site (DIRS 101811-DOE 1996, p. 4-146), which is adjacent to the proposed repository. This is slightly above the credibility level of 1×10^{-7} for accidents, as defined by DOE (DIRS 104601-DOE 1993, p. 28). However, most tornadoes in the western United States have relatively modest wind speeds.

    For example, the probability of a tornado with wind speeds greater than 100 miles per hour is 0.1 or less (DIRS 103693-Ramsdell and Andrews 1986, p. 41). Thus, winds strong enough to damage the Waste Handling Building are considered to be not credible.

    Tornadoes can generate missiles that could affect structures at the repository, but radioactive material would be protected either by shipping casks, the Waste Handling Building with thick concrete walls, or the transporter. Structures, systems, and components that could be vulnerable to tornado missile impacts would either be protected from the missiles, designed to withstand a missile impact, or shown to not interact with a missile by a probabilistic analysis (DIRS 153849-DOE 2001, p. 5-15). Therefore, tornado-driven missiles would not be a credible hazard.

16. **Volcanism, Ash Fall.** The potential for volcanic activity at the proposed repository site has been studied extensively. A recent assessment (DIRS 151945-CRWMS M&O 2000, p. 12.2-4) estimates that the mean annual frequency of a volcanic event that would intersect the repository footprint would be 1.6×10^{-8} per year (with 5-percent and 95-percent bounds of 7.6×10^{-10} and 5×10^{-8} per year, respectively), which is below the frequency of a reasonably foreseeable event for evaluation as an accident. Igneous activity scenarios are, however, evaluated as part of long-term performance (Chapter 5, Section 5.7.2). This result is consistent with a previous study of volcanic activity at the site (DIRS 101779-DOE 1998, all). Impacts from a regional volcanic eruption would be more likely; such an event could produce ash fall on the repository, and would be similar to the sandstorm event discussed above. Ash fall, if thick enough, could produce a very heavy loading on the roof of the Waste Handling Building. Studies have concluded, however, that the worst-case event would be an ash fall depth of 3 centimeters (1.2 inches), and analyses to date indicate that repository structures would not be affected by a 3-centimeter ash fall (DIRS 101779-DOE 1998, Volume 2, pp. 2-9). Furthermore, the extreme consequence of excessive ashfall on the Waste Handling Building would be collapse of the building from excessive weight. Therefore, this event is bounded by the seismic event that caused collapse. The potential of a volcanic event affecting postclosure repository performace is discussed in Chapter 5, Section 5.7.2.

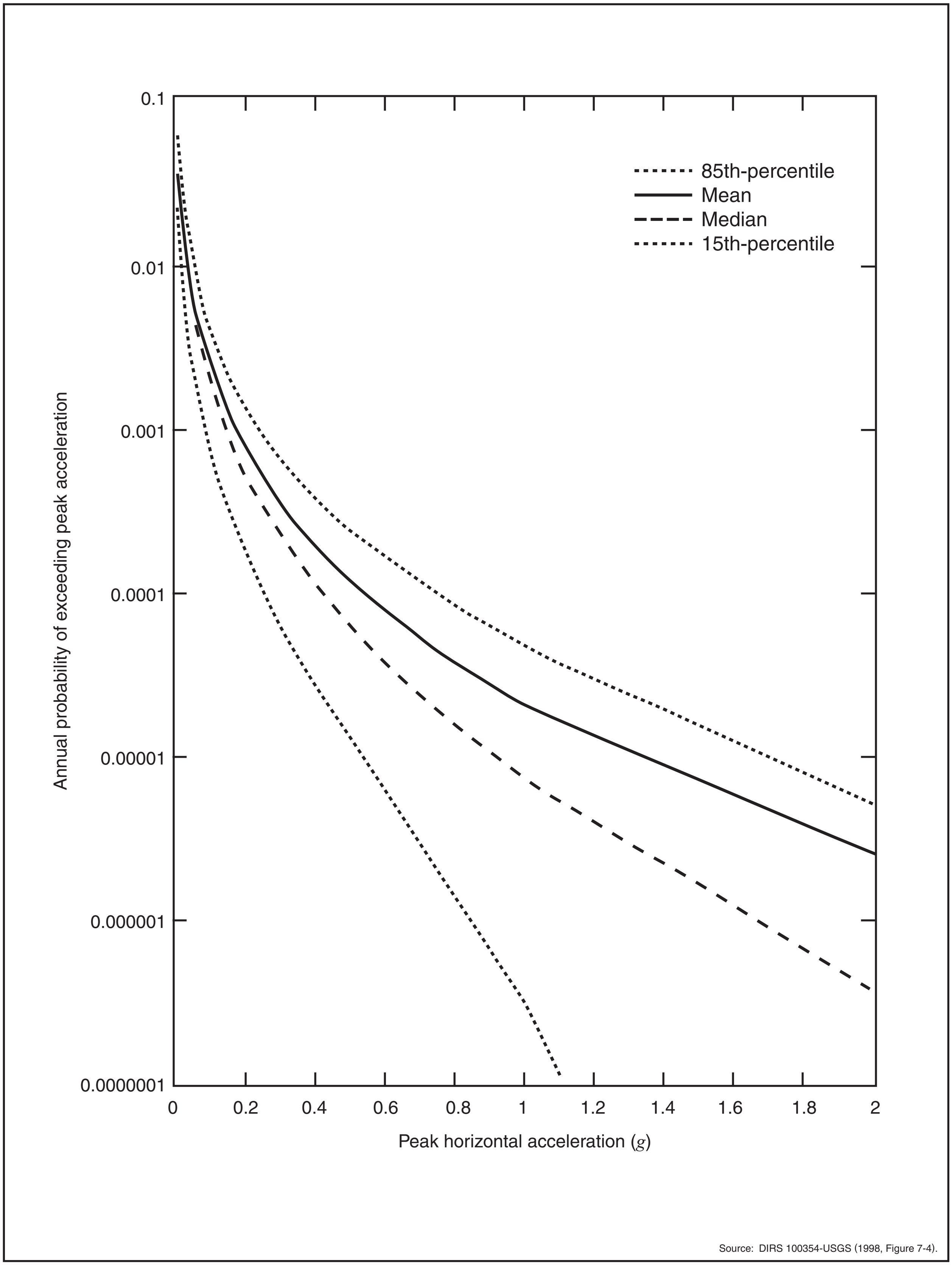

Figure H-1. Integrated seismic hazard results: summary hazard curves for peak horizontal acceleration.

17. Sabotage. In the aftermath of the tragic events of September 11, DOE is continuing to assess measures that it could take to minimize the risk or potential consequences of radiological sabotage or terrorist attacks against our Nation's proposed monitored geologic repository.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level radioactive waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (prior to closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by Federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

Current Nuclear Regulatory Commission regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides "high assurance that activities involving spent nuclear fuel and high-level waste do not constitute an unreasonable risk to public health and safety." The regulations require that spent nuclear fuel and high-level radioactive waste be stored in a protected area such that:

- Access to the material requires passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, be continually monitored, and be protected by an active alarm system.
- Adequate illumination must be provided for observation and threat assessment.
- The area must be monitored by random patrol.
- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

A trained, equipped, and qualified security force is required to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat. Liaison with a response force is required to permit timely response to unauthorized entry or activities. In addition, the Nuclear Regulatory Commission requires (10 CFR Part 63, by reference to 10 CFR Part 72) that comprehensive receipt, periodic inventory, and disposal records be kept for spent nuclear fuel and high-level radioactive waste in storage. A duplicate set of these records must be kept at a separate location.

DOE believes that the safeguards applied to the proposed repository should involve a dynamic process of enhancement to meet threats, which could change over time. Repository planning activities would continue to identify safeguards and security measures that would further protect fixed facilities from terrorist attack and other forms of sabotage. Additional measures that DOE could adopt include:

- Facilities with thicker reinforced walls and roofs designed to mitigate the potential consequences of the impact of airborne objects

- Underground or surface bermed structures to lessen the severity of damage in cases of aircraft crashes
- Additional doors, airlocks, and other features to delay unauthorized intrusion
- Additional site perimeter barriers to provide enhanced physical protection of site facilities
- Active denial systems to disable any adversaries, thereby preventing access to the facility

Although it is not possible to predict if sabotage events would occur, and the nature of such events if they did occur, DOE examined various accident scenarios in this Appendix that approximate the types of consequences that could occur.

Based on the external event assessment, DOE concluded that the only external event with a credible potential to release radionuclides of concern would be a large seismic event. This conclusion is supported by previous studies that screened out all external event accident initiators except seismic events (DIRS 101930-Ma et al. 1992, p. 3-11; DIRS 104699-Jackson et al. 1984, pp. 12 and 13). As mentioned in the discussion of an accidental aircraft crash, DOE has chosen to evaluate the consequences of such an event even though the estimated frequency is below the threshold for credible events. This analysis is included in Section H.2.1.5.1.

H.2.1.3.1 *Surface Aging Facility*

As indicated previously, DOE is considering a surface aging facility as an option to enable aging of commercial spent nuclear fuel prior to emplacement. The aging process would reduce the heat generation rate from the spent nuclear fuel, which could be used to control subsurface temperatures. The design of the surface aging facility is described in detail in DIRS 155043-CRWMS M&O (2001, all). The storage facility could include up to 40,000 metric tons of heavy metal of spent nuclear fuel in individual storage modules on concrete storage pads. Spent nuclear fuel to be aged would be loaded in an overpack cask in the Waste Handling Building and moved to the surface aging facility and placed in a shielded storage cask. For this analysis, DOE assumed that the components used in the storage modules would be the same as those proposed for the Private Fuel Storage facility in Utah (DIRS 154930-NRC 2000, all), which is designed for the interim storage of commercial spent nuclear fuel. That facility has design characteristics and operation parameters similiar to those DOE would use for the surface aging facility at the proposed repository. The surface aging facility design would conform to the same safety requirements as that for the Private Fuel Storage facility.

In evaluating potential accidents at the surface aging facility, DOE assumed that the results of the Private Fuel Storage facility safety analysis would generally apply (DIRS 154930-NRC 2000, all). On the basis of that safety analysis and site-specific characteristics of the proposed repository, DOE determined that only two accidents, both external events, would have the potential to release radioactivity to the environment. These accidents are a beyond-design-basis earthquake event and an aircraft crash into storage modules.

The surface aging facility would be designed to withstand the design-basis earthquake without tipover of the storage modules, in compliance with Nuclear Regulatory Commission requirements. A beyond-design-basis earthquake, however, could be a credible event, so DOE evaluated it. The most significant consequences of a beyond-design-basis earthquake would be tipover of the storage modules containing the overpack cask and storage canister. Such an event would not result in a release because tipover of the storage overpack cask would not impair the ability of the cask to maintain confinement of the stored fuel (DIRS 154930-NRC 2000, p.165).

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For the aircraft crash event, DOE determined, as evaluated in Section H.2.1.3, that a crash involving a military aircraft from Nellis Air Force Base could be a reasonably forseeable event if the entire storage capacity was being used. As a consequence, an analysis of the penetration capability of a crashing aircraft determined that the limiting aircraft missiles from Nellis Air Force Base aircraft would not penetrate the storage modules (DIRS 157108-Jason 2001, all). This result was based on analysis of the Private Fuel Storage module design (DIRS 154930-NRC 2000, all), which includes an inner storage canister, an overpack cask with thick steel walls, and a shielded outer cask consisting of steel shells enclosing a concrete annulus 70 centimeters (28 inches) thick. Other designs that DOE could select for the surface aging facility would have similar characteristics to meet applicable requirements.

H.2.1.4 Source Terms for Repository Accident Scenarios

Following the definition of the accident scenarios as provided in previous sections, the analysis then estimated a source term for each accident scenario retained for analysis. The source term is an estimate of the amount of material released, which is used in estimating radiological impacts from accidents. The source term specification needed to include several factors, including the quantity of radionuclides released, the elevation of the release, the chemical and physical forms of the released radionuclides, and the energy (if any) of the plume that would carry the radionuclides to the environment. These factors would be influenced by the state of the material involved in the accident and the extent and type of damage estimated for the accident sequence. The estimate of the source term also considered mitigation measures, either active (for example, filtration systems) or passive (for example, local deposition of radionuclides or containment), that would reduce the amount of radioactive material released to the environment.

The analysis developed the source term for each accident scenario retained for evaluation. These include the accident scenarios retained from the internal events as listed in Table H-1 and the seismic event retained from the external event evaluation. Because many of the internal event-initiated accidents would involve drops of commercial spent nuclear fuel, the analysis considered the source term for these accidents as a group. Accordingly, source terms were developed for the following accident scenarios: commercial spent nuclear fuel drops, transporter runaway and derailment, seismic event, and low-level waste drum failure. The source term for the accidental aircraft crash into the repository surface facilities is described in Section H.2.1.5.1.

For accident releases that would be filtered through high-efficiency particulate air filters by the heating, ventilation, and air conditioning system, the analysis assumed a retention factor of 0.99 for particulates, consistent with DIRS 150276-CRWMS M&O (2000, p. 21).

H.2.1.4.1 *Commercial Spent Nuclear Fuel Drop Accident Scenario Source Term*

Commercial spent nuclear fuel contains nearly 400 radionuclides (DIRS 100181-SNL 1987, Appendix A). Not all of these radionuclides, however, would be important in terms of a potential to cause adverse health effects (radiotoxicity) if released, and many would have decayed by the time the material arrived at the repository. Based on the characteristics of the radioactivity associated with a radionuclide (including type and energy of radioactive emissions, amount produced during the fissioning process, half-life, physical and chemical form, and biological impact if inhaled or ingested by a human), particular radionuclides could be meaningful contributors to health effects if released. To determine the important radionuclides for an accident scenario consequence analysis, DOE consulted several sources. The Nuclear Regulatory Commission has identified a minimum of eight radionuclides in commercial spent nuclear fuel that "must be analyzed for potential accident release" (DIRS 101903-NRC 1997, p. 7-6). Repository accident scenario evaluations (DIRS 100181-SNL 1987, pp. 5-3 and 5-4) identified 14 isotopes (five of which were also on the Nuclear Regulatory Commission list) that contribute to

"99 percent of the total dose consequence." A more recent accident consequence evaluation (DIRS 150276-CRWMS M&O 2000, Attachment VIII) used a total of 51 radionuclides that included all of those discussed above. DOE used this same list for the EIS accident impact evaluations (see Appendix A, Section A.2.1.5.2).

Commercial spent nuclear fuel includes two primary types—boiling-water reactor and pressurized-water reactor spent fuel. For these commercial fuels, the radionuclide inventory depends on burnup (power history of the fuel) and cooling time (time since removal from the reactor). The EIS accident scenario analysis used "representative" fuels for each type. These fuels were defined on the basis of a relative hazard evaluation (see Appendix A, Section A.2.1.5). Table H-3 lists the characteristics of representative commercial spent nuclear fuel types. Table H-4 lists the radionuclide inventory selected for estimating the accident scenario consequences for the fuel types selected (representative boiling-water reactor and pressurized-water reactor).

Table H-3. Representative commercial spent nuclear fuel characteristics.[a]

Fuel type[b]	Cooling time (years)	Burnup (GWd/MTHM)[c]
PWR representative	15	50
BWR representative	14	40

a. Source: Appendix A, Section A.2.1.5.
b. PWR = pressurized-water reactor; BWR = boiling-water reactor.
c. GWd/MTHM = gigawatt-days per metric ton of heavy metal.

Commercial spent nuclear fuel damaged in the accidents evaluated in this EIS could release radionuclides from three different sources. These sources, and a best estimate of the release potential, are as follows:

H.2.1.4.1.1 Crud. During reactor operation, crud (corrosion material) builds up on the outside of the fuel rod assembly surfaces and becomes radioactive from neutron activation. Appendix A, Section A.2.1.5.2, describes the inventory of this material, which amounts to a total of 9 curies per assembly of cobalt-60 for representative pressurized-water reactor fuel and 16 curies per assembly for representative boiling-water reactor fuel.

The amount of crud that would be released from the surface of the fuel rod cladding is uncertain because there are very few data for the accident conditions of interest, and the physical condition of the crud can be highly variable (DIRS 103696-Sandoval et al. 1991, p. 18). A recent comprehensive assessment (DIRS 152476-Sprung et al. 2000, Section 7) of crud release potential under accident conditions involving commercial spent nuclear fuel estimated that 10 percent of the crud would flake off during events involving mechanical impacts to the fuel assemblies (DIRS 152476-Sprung et al. 2000, p. 7-49). DOE used this value for repository accident analyses for events involving mechanical impact to the assemblies.

Following their release from the cladding, some crud particles would be retained by deposition on the surrounding surfaces (the fuel assembly cladding, spacer grids and structural hardware). The estimated fraction of released particles deposited on these surfaces would be 0.9 (DIRS 100181-SNL 1987, p. 5-27), resulting in an escape fraction of 0.1. In accidents involving casks or canisters, additional surfaces represented by these components would offer surfaces for further plateout.

The inhalation radiation dose from cobalt-60 (or any radioactive particle) depends on the amount of particulate material inhaled into and remaining in the lungs (called the respirable fraction). The analysis

Table H-4. Inventory used for representative commercial spent nuclear fuel (curies per assembly).[a,b,c]

Isotope	Location	Pressurized-water reactor	Boiling-water reactor
Hydrogen-3	Fuel clad gap	2.0×10^{2}	66
Carbon-14	Fuel clad gap	0.31	0.16
Chlorine-36	Fuel clad gap	6.3×10^{-3}	2.6×10^{-3}
Iron-55	Nonfuel structures	40	16
Cobalt-60	Nonfuel structures	1.1×10^{-3}	1.7×10^{2}
Cobalt-60	Assembly surface (crud)	8.8	16
Nickel-59	Nonfuel structures	1.9	0.45
Nickel-63	Nonfuel structures	2.5×10^{2}	57
Selenium-79	Fuel pellet	4.6×10^{-2}	1.4×10^{-2}
Krypton-85	Fuel clad gap	2.2×10^{3}	7.0×10^{2}
Strontium-90	Fuel pellet, gap	3.6×10^{4}	1.1×10^{4}
Yttrium-90	Fuel pellet, gap	3.6×10^{4}	1.1×10^{4}
Zirconium-93	Fuel pellet	0.98	0.3
Niobium-93m	Fuel pellet	19	0.5
Niobium-94	Fuel pellet	0.81	1.7×10^{-2}
Technetium-99	Fuel pellet	9.1	2.9
Ruthenium-106	Fuel pellet	11	4.9
Palladium-107	Fuel pellet	7.8×10^{-2}	2.4×10^{-2}
Cadmium-113m	Fuel pellet	12	3.5
Antimony-125	Fuel pellet	1.2×10^{2}	43
Tin-126	Fuel pellet	0.37	0.11
Iodine-129	Fuel clad gap	2.2×10^{-2}	6.7×10^{-3}
Cesium-134	Fuel pellet, gap	7.2×10^{2}	2.3×10^{2}
Cesium-135	Fuel pellet, gap	0.38	0.13
Cesium-137	Fuel pellet, gap	5.2×10^{4}	1.6×10^{4}
Barium-137m	Fuel pellet, gap	5.2×10^{4}	1.6×10^{4}
Promethium-147	Fuel pellet	1.7×10^{3}	6.6×10^{2}
Samarium-151	Fuel pellet	2.4×10^{2}	53
Europium-154	Fuel pellet	1.5×10^{3}	3.9×10^{2}
Europium-155	Fuel pellet	2.2×10^{2}	75
Actinium-227	Fuel pellet	1.3×10^{-5}	0
Thorium-230	Fuel pellet	9.9×10^{-5}	3.3×10^{-5}
Protactinium-231	Fuel pellet	3.3×10^{-5}	1.2×10^{-5}
Uranium-232	Fuel pellet	2.4×10^{-2}	4.6×10^{-3}
Uranium-233	Fuel pellet	3.2×10^{-5}	0
Uranium-234	Fuel pellet	6.7×10^{-1}	0.21
Uranium-235	Fuel pellet	8.8×10^{-3}	2.4×10^{-3}
Uranium-236	Fuel pellet	0.19	5.6×10^{-2}
Uranium-238	Fuel pellet	0.14	5.7×10^{-2}
Neptunium-237	Fuel pellet	0.25	6.0×10^{-2}
Plutonium-238	Fuel pellet	2.6×10^{3}	5.7×10^{2}
Plutonium-239	Fuel pellet	1.8×10^{2}	48
Plutonium-240	Fuel pellet	3.1×10^{2}	1.0×10^{3}
Plutonium-241	Fuel pellet	3.9×10^{4}	1.0×10^{-4}
Plutonium-242	Fuel pellet	1.5	0.46
Americium-241	Fuel pellet	1.5×10^{3}	3.7×10^{2}
Americium-242m	Fuel pellet	7.2	2.1
Americium-243	Fuel pellet	20	4.8
Curium-242	Fuel pellet	5.9	1.7
Curium-243	Fuel pellet	13	2.9
Curium-244	Fuel pellet	1.8×10^{3}	3.5×10^{2}
Curium-245	Fuel pellet	0.29	3.6×10^{2}
Curium-246	Fuel pellet	9.1×10^{-2}	1.3×10^{-2}

a. Source: Appendix A.
b. Inventory numbers have been rounded to two significant figures.
c. The analysis included yttrium-90 and barium-137m and assumed them to be in equilibrium with strontium-90 and cesium-137, respectively.

assumed that the respirable fraction would be 0.05 (based on DIRS 104724-Wilmot 1981, p. B-3). Therefore, the analysis assumed that the total cobalt-60 respirable airborne release fraction would be 0.0005 (the flake off fraction of 0.1 multiplied by the amount not deposited on fuel assembly surfaces of 0.1 multiplied by the respirable fraction of 0.05) for accident scenarios involving commercial spent nuclear fuel.

H.2.1.4.1.2 Fuel Rod Gap. The space between the fuel rod cladding and the fuel pellets (called the *gap*) contains radionuclides released from the fuel pellets during reactor operation. The only potentially important radionuclides in the gap are the gases tritium (hydrogen-3) and krypton-85, and the volatile radionuclides strontium-90, cesium-134, cesium-137, ruthenium-106, and iodine-129 (DIRS 101903-NRC 1997, p. 7-6). In addition, the analysis considered carbon-14, which it assumed to reside in the gaps as a gas. The Nuclear Regulatory Commission recommends fuel rod release fractions (the fraction of the total fuel rod inventory) of 0.3 for tritium and krypton-85, 0.000023 for the strontium and cesium components, 0.000015 for ruthenium-106, and 0.1 for iodine under accident conditions that rupture the cladding (DIRS 101903-NRC 1997, p. 7-6). The carbon-14 release fraction was assumed to be the same as the radioactive gases in the gap, tritium, and krypton-85 (release fraction of 0.3). Chlorine-36 was assumed to be combined with cesium and, therefore, would have the same release fraction (2.3×10^{-5}). These assumptions are consistent with releases assumed for transportation accidents (see Appendix J, Section J.1.4.2). The release fraction for the gases (tritium and krypton), as expected, would be rather high because most of the gas would be in the fuel rod gap and under pressure inside the fuel rod. The analysis also considered the fraction of the rods damaged in a given accident scenario. DIRS 100181-SNL (1987, p. 6-19 *et seq.*) assumed that the fraction of damaged fuel pins in each assembly involved in a collision or drop accident scenario would be 20 percent. Another assessment (DIRS 103237-CRWMS M&O 1998, p. 18) assumed that any drop of the fuel rods in a fuel assembly or basket of assemblies would result in failure of 10 percent of the fuel rods, regardless of the drop distance. Because neither value seems to have a strong basis, the EIS analysis assumed the more conservative 20-percent figure. For the particulate species released from the gap, the analysis applied a retention factor of 0.9 (escape factor of 0.1) to account for local deposition of the particles on the fuel assembly structures, consistent with (DIRS 100181-SNL 1987, p. 5-27). DIRS 100181-SNL (1987, p. 5-28) also applies a similar factor to account for retention on the failed shipping cask structures for accident scenarios involving cask failure. The final consideration is the fraction of remaining airborne particulates that would be respirable. No specific reference could be found to the volatile materials in the gap. The analysis conservatively assumed, therefore, that the respirable fraction would be 1.0.

H.2.1.4.1.3 Fuel Pellet. During reactor operation, the fuel pellets undergo cracking from thermal and mechanical stresses. This produces a small amount of pellet particulate material that contains radionuclides. The analysis assumed that the radionuclides are distributed evenly in the fuel pellets so that the fractional release of the existing pellet particulates is equivalent to the same fractional release of the total inventory of the appropriate radionuclides in the fuel pellets. If the fuel cladding failed during an accident, a fraction of these particulates would be small enough (diameter less than 10 micrometers) for release to the atmosphere and would be respirable (small enough to remain in the lungs if inhaled). Sandia National Laboratories estimates this fraction to be 0.000001 (DIRS 100181-SNL 1987, p. 5-26) based on experiments performed at Oak Ridge National Laboratory. The EIS used this value to develop source terms for the accident scenarios considered. Additional particulates could be produced by pulverization due to mechanical stresses imposed on the fuel pellets from the accident conditions. This pulverization factor has been evaluated in (DIRS 100181-SNL 1987, p. 5-17) and applied in (DIRS 103237-CRWMS M&O 1998, p. I-3). Based on experimental results involving bare fuel pellets, the analysis determined that the fraction likely to be pulverized into respirable particles would be proportional to the drop height (which is directly proportional to energy input) and would be:

> 2.0×10^{-7} × energy partition factor × unimpeded drop height (centimeters) (DIRS 103237-CRWMS M&O 1998, p. I-3).

The energy partition factor is the fraction of the impact energy that is available for pellet pulverization. A large fraction of the impact energy is expended in deforming the fuel assembly structures and rupturing the fuel rod cladding. It has been estimated (DIRS 100181-SNL 1987, p. 5-25) that the energy partition factor is 0.2.

As indicated above, some of the dispersible pellet particulates released in the accident could deposit on surfaces in the vicinity of the damaged fuel. Consistent with the particulate material considered above, the estimated fraction that would not deposit locally and would remain airborne would be 0.1 based on (DIRS 100181-SNL 1987, p. 5-26). Based on these considerations, the respirable airborne release fraction produced from pulverization of the fuel pellets would be:

$$\begin{aligned}\text{Respirable airborne release fraction} &= 2 \times 10^{-7} \times \text{drop height (centimeters)} \\ &\quad \times \text{energy partition factor} \times \text{fraction not deposited} \\ &\quad \times \text{fuel rod damage fraction} \\ &= 2 \times 10^{-7} \times \text{drop height} \\ &\quad \times 0.2 \times 0.1 \\ &\quad \times 0.2 \\ &= 8 \times 10^{-10} \times \text{drop height}\end{aligned}$$

This result is reasonably consistent with the value of 8×10^{-7} from (DIRS 103695-SAIC 1998, p. 3-9), which is characterized as a bounding value for the respirable airborne release fraction for accident scenarios that would impose mechanical stress on fuel pellets for a range of energy densities (drop heights). This value would correspond to a drop from 1,000 centimeters (10 meters or 33 feet) based on the formulation above.

H.2.1.4.1.4 Conclusions. Table H-5 summarizes the source term parameters for commercial spent nuclear fuel drop accident scenarios, as discussed above.

Table H-5. Source term parameters for commercial spent nuclear fuel drop accident scenarios.

Radionuclide[a]	Location	Damage fraction	Release fraction	Fraction not deposited	Respirable fraction	Respirable airborne release fraction
Co-60	Clad surface	1.0	0.1	0.1	0.05	0.0005
H-3, Kr-85, C-14	Gap	0.2	0.3	1.0	1.0	0.06
I-129	Gap	0.2	0.1	1.0	1.0	0.02
Cs-137, Sr-90, Cl-36	Gap	0.2	2.3×10^{-5}	0.1	1.0	4.6×10^{-7}
Ru-106	Gap	0.2	1.5×10^{-5}	0.1	1.0	3.0×10^{-7}
All solids	Gap (existing fuel particulates)	0.2	1.0×10^{-6}	0.1	1.0	2.0×10^{-8}
All solids	Pellet-pulverization	0.2	$4.0 \times 10^{-8} \times h$[b]	0.1	1.0	$8.0 \times 10^{-10} \times h$[b]

a. Abbreviations: Co = cobalt; H = hydrogen (H-3 = tritium); Kr = krypton; C = carbon; I = iodine; Cs = cesium; Sr = strontium; Cl = chlorine; Ru = ruthenium.

b. h = drop height in centimeters; depends on specific accident scenarios.

H.2.1.4.2 *Transporter Runaway and Derailment Accident Source Term*

This accident, as noted in Section H.2.1.3, would involve the runaway and derailment of the waste package transporter. It assumes the ejection of the waste package from the transporter during the event;

the waste package would be split open by impact on the access tunnel wall. The calculated maximum impact speed would be 18 meters per second (38 miles per hour) (DIRS 102702-CRWMS M&O 1997, p. 98). This analysis assumed that the source term from the damage to the 21 pressurized-water reactor fuel assemblies in the waste package is equivalent to a drop height that would produce the same impact velocity (equivalent to the same energy input). The equivalent drop height was computed from basic equations for the motion of a body falling under the influence of gravity:

velocity = acceleration × time

and,

distance = ½ × acceleration × time squared

where: velocity = velocity of the impact (18 meters per second)
time = time required for the fall
acceleration = acceleration due to gravity (9.8 meters per second squared)

By substitution,

$$\text{distance} = \tfrac{1}{2} \times \text{acceleration} \times (\text{velocity} \div \text{acceleration})^2 = (\text{velocity})^2 \div (\text{acceleration} \times 2) = (18)^2 \div (9.8 \times 2) = 16 \text{ meters}$$

Thus, the calculation of the source term for this accident scenario assumed a drop height of 16 meters and used the parameters in Table H-5 for the various nuclide groups.

H.2.1.4.3 *DOE Spent Nuclear Fuel Drop Accident Source Term*

Because the analysis identified no repository accidents that could result in releases of radionuclides from DOE spent nuclear fuel that exceeded limits established by the Nuclear Regulatory Commission, the source term for such accidents is not important in this environmental impact analysis. Furthermore, as indicated in the Draft EIS (Appendix H, p. H-7), the maximum consequences for credible accidents involving bounding DOE spent nuclear fuel would be much less than equivalent accidents involving commercial spent nuclear fuel.

H.2.1.4.4 *Seismic Accident Scenario Source Term*

Waste Handling Building. In this event, as noted in Section H.2.1.3, the Waste Handling Building could collapse from a beyond-design-basis earthquake. Bare fuel assemblies being transferred during the event would be likely to drop to the floor and concrete from the ceiling could fall on the fuel assemblies, causing damage that could result in radioactive release, which would discharge to the atmosphere through the damaged roof. In addition, other radioactive material stored or being handled in the Waste Handling Building could be vulnerable to damage. To estimate the source term, the analysis evaluated the extent of damage to the fuel rods and pellets for the assemblies being transferred and then examined the other material that could be vulnerable.

The ceiling of the transfer cell, which would consist of concrete 20 to 25 centimeters (8 to 10 inches) thick, would be about 15 meters (50 feet) high (DIRS 104508-CRWMS M&O 1999, Attachment IV, Figure 13). Typical pressurized-water reactor fuel assemblies weigh 660 kilograms (1,500 pounds) each (see Appendix A, Section A.2.1.5.5). The assemblies are about 21 centimeters (8.3 inches) wide by about 410 centimeters (160 inches) long, for an effective cross-sectional area (horizontal) of 1 square meter

(11 square feet) (DIRS 100181-SNL 1987, p. 5-2). The weight of a single fuel assembly is roughly equivalent to a 25-centimeter-thick concrete block with a 1-square-meter cross-section [about 750 kilograms (1,700 pounds) based on a density of 2.85 grams per cubic centimeter (180 pounds per cubic foot) (DIRS 103178-Lide and Frederikse 1997, p. 15-28)]. Thus, as a first approximation, the analysis assumed that the concrete blocks falling from the ceiling onto the fuel assemblies would produce about the same energy as the fuel assemblies falling from the same height.

Some of the energy imparted to the fuel assemblies from the falling debris would be absorbed in deforming the fuel assembly structures and, thus, would not be available to pulverize the fuel pellets. As evaluated above for falling fuel assemblies, this energy absorption factor would result in an estimated 20 percent of the energy being imparted to the pellets and the rest absorbed by the structure (DIRS 100181-SNL 1987, p. 5-25). Finally, as noted above, the analysis used a 0.1 release factor (0.9 retention) to represent the retention of the released fuel particles by deposition on the cladding and other fuel assembly structures (DIRS 100181-SNL 1987, p. 5-27). In addition, it assumed that additional retention would be associated with the concrete and other rubble that would be on top, or in the vicinity, of the fuel assemblies. It assumed this release factor would be 0.1 (0.9 retention) consistent with that used by (DIRS 100181-SNL 1987, p. 5-28) for retention by deposition on the cask and canister materials that surround the fuel assemblies during accident scenarios. It also assumed a fuel pellet pulverization factor of $8 \times 10^{10} \times h$, the same as that used for fuel assembly drop accident scenarios. Thus, the overall pellet respirable airborne release fraction for the fuel pellet particulates is:

$$\begin{aligned}\text{Respirable airborne release fraction} &= 8 \times 10^{-10} \times \text{drop height (centimeters)} \times \text{rubble release factor} \\ &= 8 \times 10^{-10} \times 1{,}500 \times 0.1 \\ &= 1.2 \times 10^{-7}\end{aligned}$$

Other radioactive materials either stored or being handled in the Waste Handling Building could also be at risk. For material in casks and canisters and waste packages, the analysis assumed that the damage potential from falling debris would not be great enough to cause a large radionuclide release. This is based on the fact that canisters and casks are quite robust and that, even if the containers were breached by the energy of the impact, there would be very little energy remaining to cause fuel pellet pulverization. There could be, however, bare fuel assemblies exposed in the dryers and in disposal containers awaiting lid attachment. An estimated 294 bare pressurized-water reactor fuel assemblies could be exposed to falling debris (DIRS 152579-Montague 2000, p. 1). The location of this material would be as follows:

- Assembly transfer system dryers: 84 pressurized-water reactor assemblies
- Disposal canister handling system welding stations: 168 pressurized-water reactor assemblies
- Assembly transfer system load port: 42 pressurized-water reactor assemblies

Because the concrete roof heights over these areas would be roughly the same as the assembly transfer system area in the Waste Handling Building [15 meters (50 feet)] where the analysis assumed the four bare pressurized-water reactor assemblies would be involved, the analysis assumed the pellet pulverization contribution to the source term to be equivalent to that for the fuel assemblies being transferred. The overall source term, then, was determined by assuming 294 representative pressurized-water reactor assemblies with the release fractions listed in Table H-5.

Boiling-water reactor fuel assemblies could be exposed at these areas, but the analysis evaluated only pressurized-water reactor fuel assemblies because they would result in a slightly higher source term under equivalent accident conditions and would be more likely to be involved because they would comprise a larger amount of material (see Appendix A, Section A.2.2.1) to be received at the repository.

Bare spent nuclear fuel assemblies stored in the blending inventory pools or the assembly holding pool could be vulnerable to damage from the postulated earthquake. However, the Waste Handling Building enclosure over the pool areas would be a steel frame structure that would not have a thick concrete slab roof. Therefore, there would be no heavy concrete blocks to fall into the pools and cause extensive damage to the stored fuel assemblies. The 15-meter (50-foot) depth of the pools would also limit the velocity of impact (and therefore impact damage) of any debris that might enter the pool from the postulated earthquake. Further, if a radionuclide release were to occur from damage to spent fuel assemblies in a pool, the release would be very small because the radionuclides contained in the fuel pellet particles would be retained in the pool water, and releases would therefore be minimal (DIRS 147496-CRWMS M&O 2000, p. 51). Because the pools would be below ground level, would be constructed of reinforced concrete, and would have steel liners, rapid draining of the pools would not be expected from earthquake damage.

Waste Treatment Building. It is assumed that the radionuclide concentration for the dry compactible waste in the Waste Treatment Building would be similar to that for power reactors (DIRS 104701-McFeely 1998, p. 2). This material would consist of paper, plastic, and cloth with a specific activity of 0.025 curie per cubic meter (0.7 millicurie per cubic foot) (DIRS 104701-McFeely 1998, p. 2). This activity would consist primarily of cobalt isotopes (primarily cobalt-60) representing 67 percent of the total activity, and cesium, which would contribute 28 percent of the total (DIRS 104702-McFeely 1999, all).

The Waste Treatment Building would operate a single shift per day, and would continuously process waste such that no large accumulation would occur. Because Waste Handling Building operations would be likely to involve three shifts per day (DIRS 104508-CRWMS M&O 1999, Section 6.2), the analysis assumed that three shifts of solid waste would accumulate before the Waste Treatment Building began its single-shift operation. The generation rate of solid compactible waste would be about 1,500 cubic meters (53,000 cubic feet) per year (DIRS 100217-CRWMS M&O 1997, p. 32) or about 0.17 cubic meter (5.8 cubic feet) per hour. Thus, three shifts (24 hours) of Waste Handling Building operation would produce about 4.0 cubic meters (140 cubic feet) of solid compactible waste. The total radionuclide inventory in this waste would be:

Cobalt-60 = 4.0 cubic meters × 0.025 curie per cubic meters × 0.67 (cobalt-60 fraction)
≅ 0.07 curie

Cesium-137 = 4.0 cubic meters × 0.025 curie per cubic meters × 0.28 (cesium-137 fractions)
≅ 0.03 curie

The respirable airborne release fraction for a fire involving combustible low-level waste has been conservatively estimated at 0.4 (DIRS 103688-Mueller et al. 1996, p. D-21). Thus, the respirable airborne release source term for the fire accident scenario would be:

Cobalt-60 = 0.07 curie × 0.4 = 0.028 curie
Cesium-137 = 0.03 curie × 0.4 = 0.012 curie

The assumed release height for the accident scenario is 2 meters (6.6 feet). This is the minimum release height for the consequences analysis and represents a ground-level release.

H.2.1.4.5 *Low-Level Waste Drum Failure Source Term*

As indicated in Section H.2.1.2, the most meaningful accident scenarios involving exposure to workers would be those related to puncture or rupture of waste drums that contained low-level waste. Such events could occur during handling operations and probably would involve the puncture of a drum by a forklift, or the drop of the drum during stacking and loading operations.

Two types of waste drums would contain the processed waste. Concentrated liquid waste would be mixed with cement and poured into 0.21-cubic-meter (55-gallon) drums. Compacted and noncompacted solid waste would also be placed in the same drums, which would, in turn, be placed in 0.32-cubic-meter (85-gallon) drums with the space between the two drums grouted. The probability of a drum failure was analyzed for these two drum types.

Following a drum failure, some fraction of the radionuclides in the waste would be released and workers in the immediate vicinity could be exposed to the material. The amount released would depend on the radionuclide concentration in the low-level waste material, the fraction of low-level waste released from the drum on its failure, and the respirable airborne release fraction from the released waste.

For liquid waste, the concentration of radionuclides is expected to be (DIRS 104701-McFeely 1998, p. 3):

Cobalt-60 = 0.001 curie per cubic meter
Cesium-137 = 0.0015 curie per cubic meter

As noted in Section H.2.1.2, the evaporator would concentrate the liquid waste down to 10 percent of the original generated so the concentration of radionuclides in the waste would be increased to:

Cobalt-60 = 0.01 curie per cubic meter
Cesium-137 = 0.015 curie per cubic meter

The grouting operation would dilute this concentration somewhat by adding cement, but this dilution has been ignored for conservatism.

The total activity in a 0.21-cubic meter (55-gallon) drum would become:

Cobalt-60 = 0.01 curie per cubic meter × 0.21 cubic meter
≅ 0.0021 curie per drum

Cesium-137 = 0.015 curie per cubic meter × 0.21 cubic meter
≅ 0.0032 curie per drum

For dry compacted waste, the total inventory in a 0.21-cubic-meter (55-gallon) drum would be

Cobalt-60 = 0.21 cubic meter × 0.025 curie per cubic meter × 0.67 (cobalt-60 fraction)
≅ 0.0035 curie

Cesium-137 = 0.21 cubic meter × 0.025 curie per cubic meter × 0.28 (cesium-137 fraction)
≅ 0.0015 curie

The estimated amount of material released from drums containing solid waste is 25 percent of the contents based on (DIRS 103688-Mueller et al. 1996, p. 94). Values from (DIRS 103688-Mueller et al. 1996, all) were used for the respirable airborne release fraction. For dry waste, the recommended respirable airborne release fraction is 0.001. For grouted liquid waste, this fraction is determined by the following equation:

Respirable airborne release fraction = $A \times D \times G \times H$

where:

A	=	constant (2.0×10^{-11}) (DIRS 103688-Mueller et al. 1996, p. D-25)
D	=	material density [3.14 grams per cubic centimeter (196 pounds per cubic foot)] (DIRS 104701-McFeely 1998, all)
G	=	gravitational acceleration [980 centimeters (32.2 feet) per second squared]
H	=	height of fall of the drum in the accident scenario

The assumed height of the fall is 2 meters (6.6 feet), which would be the approximate maximum lift height when the drum was stacked on another drum or placed on a carrier for offsite transportation. This same formula applies to drum puncture accident scenarios (DIRS 103688-Mueller et al. 1996, p. D-30), and the 2-meter drop event would be equivalent in damage potential to a forklift impact at about 4.5 meters per second (10 miles per hour). The respirable airborne release fraction for this case then becomes:

$$\text{Respirable airborne release fraction} = 2.0 \times 10^{-11} \times 3.14 \times 980 \times 200 \cong 1.23 \times 10^{-5}$$

Based on these results, the worker risk would be dominated by accidents involving drums that contained dry waste because both the frequency of the event [0.59 versus 0.46 (Section H.2.1.2)] and the release fraction [1×10^{-3} versus 1.23×10^{-5} (derived above)] would be greater. The total amount of airborne respirable material release (source term) for the risk-dominant dry waste accident scenario would be:

Cobalt-60 = 0.0035 curie (total drum inventory) × 0.25 (fraction released) × 0.001 (respirable airborne release fraction)
≅ 8.5×10^{-7} curies

Cesium-137 = 0.0015 curie (total drum inventory) × 0.25 (fraction released) × 0.001 (respirable airborne release fraction)
≅ 3.8×10^{-7} curies

The analysis assumed that, following normal industrial practice, workers would not be in the area beneath suspended objects. Accordingly, the nearest worker was assumed to be 5 meters (16 feet) from the impact area. Therefore, the volume assumed for dispersion of the material prior to reaching the worker would be 125 cubic meters (4,400 cubic feet), which represents the immediate vicinity of the accident location [a volume approximately 5 meters (16 feet) by 5 meters by 5 meters]. The breathing rate of the worker would be 0.00035 cubic meter (about 0.012 cubic foot) per second (DIRS 101074-ICRP 1975, p. 346).

H.2.1.5 Assessment of Accident Scenario Consequences

Accident scenario consequences were calculated as individual doses (rem), collective doses (person-rem), and latent cancer fatalities. The individuals considered were (1) the maximally exposed offsite individual, defined as a hypothetical member of the public at the point on the proposed repository land withdrawal boundary who would receive the largest dose from the assumed accident scenario [a minimum distance of 8 kilometers (5 miles) (DIRS 150276-CRWMS M&O 2000, p. 14)], (2) the maximally exposed involved worker, the hypothetical worker who would be nearest the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the noninvolved worker, the hypothetical worker near the accident but not involved in handling the material, assumed to be 100 meters (about 330 feet) from the accident, and (4) the members of the public who reside within about 80 kilometers (50 miles) of the proposed repository.

If the total radiation dose is less than 20 rem, or the dose rate is less than 10 rem per hour, potential health effects would be chronic rather than acute. Chronic health effects could result in an increase in the risk of fatal cancer (DIRS 101836-ICRP 1991, Chapter 3) (see the discussion in Appendix F, Section F.1). The International Committee on Radiation Protection has recommended the use of a conversion factor of 0.0005 fatal cancer per person-rem for the general population for low doses, and a value of 0.0004 fatal cancer per person-rem for workers for chronic exposures. The higher value for the general population accounts in part for the fact that the general population contains young people, who are more susceptible to the effects of radiation. These conversion factors were used in the EIS consequence analysis. The latent cancer fatality caused by radiation exposure could occur at any time during the remaining lifetime of the exposed individual. As dose increases above about 15 rem over a short period (acute exposures), observable physical effects can occur, including temporary male sterility (DIRS 101836-ICRP 1991, p. 15). At even higher acute doses (above about 500 rem), death within a few weeks is probable (DIRS 101836-ICRP 1991, p. 16).

DOE used the MACCS2 computer program (DIRS 101897-Jow et al. 1990, all; DIRS 103168-Chanin and Young 1998, all) and the radionuclide source terms for the identified accident scenarios in Section H.2.1.4 to calculate consequences to individuals and populations. This program, developed by the U.S. Nuclear Regulatory Commission and DOE, has been widely used to compute radiological impacts from accident scenarios involving releases of radionuclides from nuclear fuel and radioactive waste. DOE used this program for offsite members of the public, the maximally exposed offsite individual, and the noninvolved worker. The MACCS2 program calculates radiological doses based on a sampling of the distribution of weather conditions for a year of site-specific weather data. Meteorological data were compiled at the proposed repository site from 1993 through 1997. This analysis used the weather conditions for 1993. The selection of 1993 was based on a sensitivity analysis that showed that, on the average, the weather conditions for 1993 produced somewhat higher consequences than those for the other years for most receptors, although the variation from year to year was small.

For exposure to inhaled radioactive material, it was assumed (in accordance with U.S. Environmental Protection Agency guidance) that doses would accumulate in the body for a total of 50 years after the accident (DIRS 101069-Eckerman, Wollbarst, and Richardson 1988, p. 7). For external exposure (from ground contamination and contaminated food consumption), the dose was assumed to accumulate for 30 years (DIRS 104601-DOE 1993, p. 21).

The MACCS2 program provides doses to selected individuals and populations for a contiguous spectrum of site-specific weather conditions. Two weather cases were selected for the EIS: (1) a median weather case (designated at 50 percent) that represents the weather conditions that would produce median consequences, and (2) a 95 percent weather case that provides higher consequences that would only be exceeded 5 percent of the time.

The MACCS2 program is not suitable for calculating doses to individuals near the release point of radioactive particles [within about 100 meters (330 feet)]. For such cases, the analysis calculated involved worker dose estimates using a breathing rate of 0.00033 cubic meter (0.011 cubic foot) per second (DIRS 101074-ICRP 1975, p. 346).

For involved worker doses from the drum handling accident scenario, the analysis assumed that the worker (a forklift operator) would be 3 meters (10 feet) from the drum rupture location, and would breathe air containing radioactive material from the ruptured drum for 30 seconds.

The involved worker dose estimates used the same dose conversion factors as those used by the MACCS2 program for inhalation exposure.

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The analysis assumed that the population around the repository would be that projected for 2035 (see Appendix G, Table G-48). The exposed population would consist of individuals living within about 80 kilometers (50 miles) of the repository, including pockets of people who would reside just beyond the 80-kilometer distance. The dose calculations included impacts from the consumption of food contaminated by the radionuclide releases. The contaminated food consumption analysis used site-specific data on food production and consumption for the region around the proposed site (DIRS 150276-CRWMS M&O 2000, Attachment IV, pp. IV-1 through IV-20). For conservatism, the analysis assumed no mitigation measures, such as post-accident evacuation or interdiction of contaminated foodstuffs. However, DOE would take appropriate mitigation actions in the event of an actual release.

The results of the consequence analysis are listed in Tables H-6 (for 50-percent weather) and H-7 (for 95-percent weather). These tables include the accidents retained for analysis based on the internal events evaluation described in Section H.2.1.1, the earthquake events resulting from the external events analysis in Section H.2.1.3, and an accident involving low-level waste in the Waste Treatment Building based on the evaluation in Section H.2.1.2. The tables list doses in rem for individuals and in person-rem (collective dose to all exposed persons) for the 80-kilometer (50-mile) population around the site. For selected individuals and populations, as noted, the tables list estimated latent cancer fatalities predicted to occur over the lifetime of the exposed individuals as a result of the calculated doses using the conversion factors described in this section. These estimates do not consider the accident frequency. For comparison, in 1998 the likelihood of fatal cancer from all causes for Nevada residents was about 0.24 (DIRS 153066-Murphy 2000, p. 83). Thus, the estimated latent cancer fatalities for the individuals from accidents would be very small in comparison to the cancer incidence from other causes. For the 76,000 persons expected to be living within 80 kilometers of the site in 2035 (see Appendix G), 18,240 (76,000 × 0.24) would be likely to die eventually of cancer not related to the repository. The accident of most concern for the 95-percent weather conditions (earthquake, Table H-7, number 8) would result in an estimated 0.011 latent cancer fatality for this same population. The results illustrate, by comparison of accidents 6 and 7, that accidents involving pressurized-water reactor fuel assemblies in the Waste Handling Building would produce larger impacts than equivalent accidents involving boiling-water reactor fuel assemblies.

DOE has not evaluated in detail the potential cleanup costs associated with accidents involving releases of radioactive material at the proposed repository. However, cleanup costs for transportation accidents involving material to be transported to the repository are considered in Appendix J, Section J.1.4.2.5. Such costs are highly uncertain, and depend on the type of land involved, the type of remediation action employed, and the extent of cleanup based on requirements that could exist at the time of the accident. As noted in Section J.1.4.2.5, the costs could range from about $1 million to $10 billion for severe, maximum reasonably foreseeable transportation accidents. For the repository accidents evaluated in this Appendix, DOE expects costs to be below the lower end of this range because the releases would be very small and the land near the repository would be Federally controlled, undeveloped, and uninhabited. In any event, liability for, and recovery of, costs of such accidents would be covered under provisions of the Price-Anderson Act, which currently provides for costs as high as $9.43 billion.

H.2.1.5.1 *Assessment of Consequences from Hypothetical Aircraft Crash Event*

In response to public comments and to provide further information about accident risks, DOE analyzed an accident scenario in which a large, commercial jet aircraft impacts and penetrates the Waste Handling Building, resulting in a fire. The probability of this accident is below the threshold considered reasonably foreseeable (1 in 10 million); however, if the accident occurred, the estimated consequences would include a dose of 4.5 rem to the maximally exposed offsite individual and a corresponding likelihood of 0.0023 that this individual would incur a fatal cancer as a result of the exposure. The consequences to the population for this event would be 78 person-rem and an estimated 0.039 latent cancer fatalities.

Table H-6. Radiological consequences of repository operations accidents for median (50th-percentile) meteorological conditions.

		Maximally exposed offsite individual[d]		Population		Noninvolved worker		Involved worker	
Accident scenario[a,b,c]	Frequency (per year)[a]	Dose (rem)	LCFi[e]	Dose (person-rem)	LCFp[e]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	8.2×10^{-7}	4.1×10^{-10}	4.9×10^{-4}	2.4×10^{-7}	3.6×10^{-4}	1.4×10^{-7}	(f)	(f)
2. 5-meter basket drop onto another basket in dryer (PWR fuel)	0.04	8.7×10^{-6}	4.4×10^{-9}	8.9×10^{-4}	4.4×10^{-7}	4.5×10^{-3}	1.8×10^{-6}	(f)	(f)
3. 7.6-meter drop of transfer basket onto another basket in dryer (BWR fuel)	7.4×10^{-3}	6.4×10^{-6}	3.2×10^{-9}	6.0×10^{-4}	3.0×10^{-7}	3.1×10^{-5}	1.2×10^{-8}	(f)	(f)
4. 6-meter unsealed DC drop and slapdown in cell (PWR fuel)	8.0×10^{-3}	2.6×10^{-5}	1.3×10^{-8}	2.5×10^{-3}	1.2×10^{-6}	1.3×10^{-2}	5.2×10^{-6}	(f)	(f)
5. 7.1-meter unsealed shipping cask drop in CPP (PWR fuel)	9.0×10^{-3}	3.4×10^{-5}	1.8×10^{-8}	3.0×10^{-3}	1.5×10^{-6}	1.8×10^{-2}	7.4×10^{-6}	(f)	(f)
6. Unsealed shipping cask drop in pool (PWR fuel)	9.0×10^{-3}	2.5×10^{-6}	1.3×10^{-9}	1.5×10^{-3}	7.3×10^{-7}	1.0×10^{-3}	4.1×10^{-7}	(f)	(f)
7. Transporter runaway and derailment (PWR fuel)	1.2×10^{-7}	1.0×10^{-2}	5.0×10^{-6}	0.14	7.3×10^{-5}	3.2	1.3×10^{-3}	(g)	(g)
8. Beyond design basis earthquake in WHB (PWR fuel)	2.0×10^{-5}	1.2×10^{-2}	6.0×10^{-6}	0.63	3.2×10^{-4}	4.9	2.0×10^{-3}	(g)	(g)
9. Earthquake with fire in WTB	2.0×10^{-5}	1.6×10^{-5}	8.0×10^{-9}	8.9×10^{-4}	4.4×10^{-7}	8.2×10^{-4}	3.3×10^{-7}	(g)	(g)
10. Low level waste drum rupture in WTB	0.59	5.7×10^{-10}	2.9×10^{-13}	3.0×10^{-8}	1.4×10^{-11}	2.5×10^{-8}	1.0×10^{-11}	8.8×10^{-5}	3.5×10^{-8}

a. These frequency estimates are highly uncertain due to the preliminary nature of the repository design and are provided only to show potential accident sequence credibility. They represent conservative estimates based on the approach taken in (DIRS 150276-CRWMS M&O 2000, all).

b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.

c. To convert meters to feet, multiply by 3.2808.

d. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accidents except 7. For these accidents, the distance would be 8 kilometers (5 miles).

e. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the number of cancers estimated in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as recommended by the International Council on Radiation Protection as discussed in this section.

f. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

g. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the WHB, and as many as 36 in the WTB based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The following locations were considered in the analysis:

1. Transportation casks staged at the repository
2. Waste Handling Building at the repository
3. Waste packages, either in transit at the repository, or in subsurface emplacement drifts
4. Repository surface aging facility storage modules

Table H-7. Radiological consequences of repository operations accidents for unfavorable (95th-percentile) meteorological conditions.

		Maximally exposed offsite individual[d]		Population		Noninvolved worker		Involved worker	
Accident scenario[a,b,c]	Frequency (per year)[a]	Dose (rem)	LCFi[e]	Dose (person-rem)	LCFp[e]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	3.3×10^{-6}	1.7×10^{-9}	4.0×10^{-2}	2.0×10^{-5}	2.0×10^{-3}	8.0×10^{-7}	(f)	(f)
2. 5-meter basket drop onto another basket in dryer (PWR fuel)	0.04	3.2×10^{-5}	1.6×10^{-8}	4.7×10^{-2}	2.3×10^{-5}	2.3×10^{-2}	9.2×10^{-6}	(f)	(f)
3. 7.6 meter drop of transfer basket onto another basket in dryer (BWR fuel)	7.4×10^{-3}	2.3×10^{-5}	1.2×10^{-8}	3.0×10^{-2}	1.4×10^{-5}	1.6×10^{-4}	6.4×10^{-8}	(f)	(f)
4. 6-meter unsealed DC drop and slapdown in cell (PWR fuel)	8.0×10^{-3}	9.3×10^{-5}	4.7×10^{-8}	0.12	6.2×10^{-5}	7.4×10^{-2}	3.0×10^{-5}	(f)	(f)
5. 7.1-meter unsealed shipping cask drop in CPP (PWR fuel)	9.0×10^{-3}	1.1×10^{-4}	5.5×10^{-8}	0.14	7.2×10^{-5}	0.10	4.1×10^{-5}	(f)	(f)
6. Unsealed shipping cask drop in pool (PWR fuel)	9.0×10^{-3}	1.0×10^{-5}	5.0×10^{-9}	0.12	6.0×10^{-5}	6.0×10^{-3}	2.4×10^{-6}	(f)	(f)
7. Transporter runaway and derailment (PWR fuel)	1.2×10^{-7}	3.8×10^{-2}	1.9×10^{-5}	4.3	2.2×10^{-3}	16	6.4×10^{-3}	(f)	(f)
8. Beyond design basis earthquake in WHB (PWR fuel)	2.0×10^{-5}	3.8×10^{-2}	1.9×10^{-5}	21	1.1×10^{-2}	25	9.8×10^{-3}	(g)	(g)
9. Earthquake with fire in WTB	2.0×10^{-5}	5.4×10^{-5}	2.7×10^{-8}	3.1×10^{-2}	1.5×10^{-5}	6.5×10^{-3}	2.6×10^{-6}	(g)	(g)
10. Low level waste drum rupture in WTB	0.59	1.6×10^{-9}	8.0×10^{-13}	1.1×10^{-6}	5.3×10^{-10}	2.0×10^{-7}	8.0×10^{-11}	8.8×10^{-5}	3.5×10^{-8}

a. These frequency estimates are highly uncertain due to the preliminary nature of the repository design and are provided only to show potential accident sequence credibility. They represent conservative estimates based on the approach taken in (DIRS 150276-CRWMS M&O 2000, all).

b. DC = Disposal Container; CPP = Cask Preparation Pit; PWR = Pressurized-Water Reactor; BWR = Boiling-Water Reactor; WHB = Waste Handling Building; WTB = Waste Treatment Building.

c. To convert meters to feet, multiply by 3.2808.

d. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accidents except 7. For these accidents, the distance would be 8 kilometers (5 miles).

e. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the number of cancers estimated in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as recommended by the International Council on Radiation Protection as discussed in this section.

f. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

g. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the WHB, and as many as 36 in the WTB based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

DOE determined that an aircraft crash into the Waste Handling Building would bound the impacts from the list of locations considered. This is because the Waste Handling Building would be expected to contain the largest amount of vulnerable radioactive waste and could also be penetrated by an aircraft. The amount of waste that would be contained in the Waste Handling Building during normal operations for this assessment is assumed to be 294 pressurized-water reactor fuel assemblies, consistent with the material assumed for the seismic accident event analyzed in Section H.2.1.4.4. Transportation casks would contain up to 26 pressurized-water reactor assemblies. The analysis of an aircraft crash into a transportation cask is addressed in Chapter 6, Section 6.2.4.2. The repository spent nuclear fuel surface aging facility storage modules would be composed of thick concrete shielding with concentric steel cylinders and would contain up to 21 pressurized-water reactor fuel assemblies. The analysis of an aircraft crash into the surface aging facility determined that the aircraft would not penetrate the storage modules and determined that no release would be anticipated (DIRS 157108-Jason 2001, all).

The waste packages, which would be transported one at a time from the Waste Handling Building to the emplacement drifts, would contain only 21 pressurized-water reactor assemblies. Thus, the inventory of a waste package in transit from the Waste Handling Building to the North Portal would be far less than that of the Waste Handling Building. Waste packages in the emplacement drifts would be protected by an average of about 300 meters (1,000 feet) of overburden, plus a ground support system that would reinforce the emplacement drift tunnels. Consequently, the emplaced waste packages would not be vulnerable to impact from an aircraft.

The Waste Handling Building design includes blending and staging pools that would contain large amounts of commercial spent nuclear fuel. However, these pools would be below ground level, and contain water 15 meters (50 feet) deep. Thus, the fuel that would be contained in these pools is not considered vulnerable to an aircraft crash. The aircraft could cause damage to the pools from a high angle impact, but pool drainage would be expected to be slow due to the proximity of the surrounding earth. Furthermore, the water would limit the impact velocity, and therefore the damage potential, of incoming debris from the crash. As noted previously, the pool water would also limit release of radionuclides, and protect the fuel assemblies from an aircraft fuel fire that, as shown below, could enhance radionuclide release.

The vulnerable portion of the Waste Handling Building would include the assembly transfer areas which, as noted previously, are assumed to contain 294 pressurized-water reactor fuel assemblies. While these areas would be enclosed in thick concrete walls that could resist penetration of impacting aircraft, the concrete roof of the building would be only 20 to 25 centimeters (8 to 10 inches) thick, which was determined to be insufficient to resist penetration by an impacting aircraft.

The radionuclide release from such an event would result from two sources: (1) mechanical damage to the fuel assemblies, which could rupture the zirconium alloy cladding and pulverize a portion of the fuel pellets into particles, some of which would be small enough to be transported to the nearest individual and be inhaled, and (2) a large fire involving jet fuel carried by the aircraft. In the EIS No-Action Alternative aircraft crash assessment (Scenario 2) (Appendix K, Section K.2.5.1), it was conservatively assumed that all of the fuel pellets involved in the fire following the aircraft crash would be converted from uranium dioxide to U_3O_8, producing a powder containing radionuclides. This same assumption is made for the analysis herein. Thus, because all of the fuel pellet material in the 294 pressurized-water reactor fuel assemblies is assumed to be converted to a powder form, the particulates formed by mechanical damage would not contribute further to the source term. The fire source term in the No-Action assessment assumed that 12 percent of the U_3O_8 particles would become airborne, and approximately 1 percent of the airborne particles would be small enough to be available for inhalation into the lungs of downwind individuals. The basis for these assumptions is provided in Section K.2.5.1. Therefore, the fuel pellet respirable particulate source term is assumed to be 0.0012 of all of the fuel contained in 294 pressurized-water reactor fuel assemblies in the Waste Handling Building. The radionuclide inventory in the assemblies was assumed to be the same as the representative fuel assemblies used for repository accident analysis in the EIS.

In addition to the fuel particulate source term, other sources of radionuclides would be available for release. These sources include the crud on the outside of the zirconium alloy cladding and radioactive gases (hydrogen-3, krypton-85, carbon-14, and iodine-129) in the fuel gaps. Since the zirconium alloy is expected to burn in air at 800°C (1,472°F) (DIRS 156981-NRC 2001, p. A1-1), all crud on the zircaloy is assumed to be released, and the respirable fraction is 0.05, consistent with the seismic accident analyzed in the EIS. All of the radioactive gases are assumed to be released. Based on this discussion, the release fractions listed in Table H-8 were assumed.

These release fractions were applied to the 294 commercial spent nuclear fuel pressurized-water reactor representative fuel assemblies assumed to be in the Waste Handling Building out of the pools. The resulting radionuclide source term was input to the MACCS2 program (DIRS 103168-Chanin and Young 1998, all) and doses were calculated for the nearest offsite individual and the 80-kilometer (50-mile) population for an average weather condition. A plume rise model was also used in the analysis to account

Table H-8. Assumed release fractions of crud and radioactive gases.

Radionuclide[a]	Release fraction	Fraction respirable	RARF[a]
Crud (Co-60)	100%	0.05	0.05
H-3, Kr-85, C-14, I-129	100%	1.0	1.0
All solids	0.12	0.01	1.2×10^{-3}

a. Co = cobalt; H = hydrogen (H-3 = tritium); Kr = krypton; C = carbon; I = iodine.
b. RARF = Respirable Airborne Release Fraction.

for the plume lofting from the jet fuel fire. Since the release would be large compared to other accidents analyzed in this section, it was assumed that DOE and other Federal agencies would evacuate exposed individuals after the plume passed and also interdict consumption of contaminated food and water. Accordingly, the dose associated with immersion in and inhalation of the radioactive plume from the event was computed. The dose calculations also assume that the exposed individual remained on the contaminated land for 1 day following the event, after which they are assumed to be evacuated. Table H-9 lists the results.

Table H-9. Doses from immersion in or inhalation of radioactive plume from hypothetical aircraft crash.

Receptor	Dose	LCF[a]
Maximally exposed offsite individual	4.5 rem	0.0023
80-kilometer (50-mile) population	78 person-rem	0.039

a. LCF = likelihood of a latent cancer fatality for the maximally exposed offsite individual and estimated number of latent cancer fatalities in the exposed 80-kilometer (50-mile) population.

H.2.2 NONRADIOLOGICAL ACCIDENT SCENARIOS

A potential release of hazardous or toxic materials during postulated operational accident scenarios at the repository would be very unlikely. Because of the large quantities of radioactive material, radiological considerations would outweigh nonradiological concerns. The repository would not accept hazardous waste as defined by the Resource Conservation and Recovery Act (40 CFR Parts 260 to 299). Some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. However, they would be in a solid glass matrix that would make the exposure of workers or members of the public from operational accidents highly unlikely. Appendix A contains more information on the inventory of potentially hazardous materials.

Some potentially nonradioactive hazardous or toxic substances would be present in limited quantities at the repository as part of operational requirements. Such substances would include liquid chemicals such as cleaning solvents, sodium hydroxide, sulfuric acid, and various solid chemicals. These substances are in common use at other DOE sites. Potential impacts to workers from normal industrial hazards in the workplace including workplace accidents were derived from DOE accident experience at other sites. These impacts include those from accident scenarios involving the handling of hazardous materials and toxic substances as part of typical DOE operations. Thus, the industrial health and safety impacts to workers include impacts to workers from accidents involving such substances.

Impacts to members of the public would be unlikely because the hazardous materials would be mostly liquid and solid rather than gaseous so that a release would be confined locally. (For example, chlorine used at the site for water treatment would be in powder form, so a gaseous release of chlorine would be unlikely. Furthermore, the repository would not use propane as a heating fuel, so no potential exists for propane explosions or fires.) The potential for hazardous chemicals to reach surface water during the Proposed Action would be limited to spills or leaks followed immediately by a rare precipitation or snow melt event large enough to generate runoff. Throughout the project, DOE would install engineered measures to minimize the potential for spills or releases of hazardous chemicals and would comply with written plans and procedures to ensure that, if a spill did occur, it would be properly managed and remediated. The Spill Prevention Control and Countermeasures Plan that would be in place for Yucca Mountain activities is an example of the plans DOE would follow under the Proposed Action.

The construction phase could generate as many as 3,500 drums [about 730 cubic meters (26,000 cubic feet)] of solid hazardous waste, and emplacement operations could generate as much as 100 cubic meters (3,500 cubic feet) per year (DIRS 104508-CRWMS M&O 1999, Section 6.1). Maintenance operations and closure would generate similar or smaller waste volumes. DOE would accumulate this waste in onsite staging areas in accordance with the regulations of the Resource Conservation and Recovery Act. Emplacement and maintenance operation could generate as many as 2,700 liters (1,700 gallons) of liquid hazardous waste annually (DIRS 104508-CRWMS M&O 1999, Table 6-2). The construction and closure phases would not generate liquid hazardous waste. The generation, storage, packaging, and shipment off the site of solid and liquid hazardous waste would present a very small potential for accidental releases and exposures of workers. Although a specific accident scenario analysis was not performed for these activities, the analysis of human health and safety (see Chapter 4, Section 4.1.7.3) included these impacts to workers implicitly through the use of a data base that includes impacts from accidents involving hazardous and toxic materials. Impacts to members of the public would be unlikely.

H.3 Accident Scenarios During Retrieval

During retrieval operations, activities at the repository would be essentially the reverse of waste package emplacement, except operations in the Waste Handling Building would not be necessary because the waste packages would not be opened. The waste packages would be retrieved remotely from the emplacement drifts, transported to the surface, and transferred to a Waste Retrieval Storage Facility (DIRS 104508-CRWMS M&O 1999, Attachment I). This facility would include a Waste Retrieval Transfer Building where the waste packages would be unloaded from the transporter, transferred to a concrete storage unit, and moved to a concrete storage pad. The storage pad would be a 24- by 24-meter (80- by 80-foot) pad, about 1 meter (3.3 feet) thick, which probably would be located about 3 kilometers (2 miles) over flat terrain from the North Portal. Each storage pad would contain 14 waste packages. The number of pads required would depend on how many waste packages would be retrieved.

Because retrieval operations would be essentially the reverse of emplacement operations, accidents involving the disposal container during emplacement bound the retrieval operation. The bounding accident scenario during emplacement of the disposal container would be transporter runaway and derailment in the access tunnel (see Section H.2.1.4). This accident scenario would also bound accident scenarios during retrieval.

During storage, no credible accidents resulting in radioactive release of any measurable consequence would be expected to occur. This conclusion is based on the analysis of accidents for the surface aging facility evaluated in this section and is also consistent with dry storage accident evaluations at commercial sites under similar conditions, as evaluated in Appendix K.

In view of these considerations, DOE has concluded that the waste transporter derailment accident scenario analyzed in Section H.2 would bound accident impacts during retrieval.

H.4 Accident Scenarios During Monitoring and Closure

During monitoring and closure activities, DOE would not move the waste packages, with the possible exception of removing a container from an emplacement drift for examination or drift maintenance. Such operations could result in a transporter runaway and derailment accident, but the frequency of release from such an event would be extremely low, as would the consequences, resulting in minimal risk. Thus, DOE expects the radiological impacts from operations during monitoring and closure to be very small.

H.5 Accident Scenarios for Inventory Modules 1 and 2

Inventory Modules 1 and 2 are alternative inventory options that the EIS considers. These modules involve the consideration of additional waste material for emplacement in the repository. They would involve the same waste and handling activities as those for the Proposed Action, but the quantity of materials received would increase, as would the period of emplacement operations. The analysis assumed the receipt and emplacement rates would remain the same as those for the Proposed Action. Therefore, DOE expects the accident impacts evaluated for the Proposed Action to bound those that could occur for Inventory Modules 1 and 2 because the same set of operations would be involved.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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Appendix J

Section J.1.3.2.2.3
Figures J-8a and J-8b from Section J.1.4.2.1
Section J.2.4.3.1
Aircraft Crash Accident from Section J.3.3.1

J.1.3.2.2.3 Incident-Free Radiation Doses to Escorts. Transporting spent nuclear fuel to the Yucca Mountain site would require the use of physical security and other escorts for the shipments. Regulations (10 CFR 73.37) require escorts for highway and rail shipments. These regulations require two escorts (individuals) for truck shipments traveling in highly populated (urban) areas. One of the escorts must be in a vehicle that is separate from the shipment vehicle. For rail shipments in urban areas, at least two escorts must maintain visual surveillance of a shipment from a railcar that accompanies a cask car.

In areas that are not highly populated (suburban and rural), one escort must accompany truck shipments. The escort can ride in the cab of the shipment vehicle. At least one escort is required for rail shipments in suburban and rural areas. However, for rail shipments, the escort must occupy a railcar that is separate from the cask car and must maintain visual surveillance of the shipment at all times.

For legal-weight truck shipments, the analysis assumed that a second driver, who would be a member of the vehicle crew, would serve as an escort in all areas. The analysis assigned a second escort for travel in urban areas and assumed that this escort would occupy a vehicle that followed or led the transport vehicle by at least 60 meters (about 200 feet). The analysis assumed that the dose rate at a location 2 meters (6.6 feet) behind the vehicle would be 10 millirem per hour, which is the limit allowed by U.S. Department of Transportation regulations (49 CFR 173.441). Using this information, the analysis used the RISKIND computer program to calculate a value of approximately 0.15 millirem per hour for the dose rate 60 meters behind the transport vehicle; this is the estimated value for the dose rate in a following escort vehicle. The value for the dose rate in an escort vehicle that preceded a shipment would be lower. Because the dose rate in the occupied crew area of the transport vehicle would be less than 2 millirem per hour, the dose rate 2 meters in front of the vehicle would be much less than 10 millirem per hour, the value assumed for a location 2 meters behind the vehicle. The value of 2 millirem per hour in normally occupied areas of transport vehicles is the maximum allowed by U.S. Department of Transportation regulations (49 CFR 173.441).

To calculate the dose to escorts, the analysis assumed that escorts in separate vehicles would be required in urban areas as shipments traveled to the Yucca Mountain site. The calculations used the RISKIND computer program (DIRS 101483-Yuan et al. 1995, all); the distance of travel in urban areas provided by the HIGHWAY and INTERLINE computer codes; and the estimated speed of travel in urban areas based on data in Table J-15 to estimate the dose to escorts. For example, truck shipments could be escorted through an average of five urban areas on average for 30 minutes in each. Using these assumptions and the estimated dose rate in an escort vehicle, the estimated dose for escorts in separate vehicles is 0.38 millirem per shipment (0.38 millirem = 5 areas per shipment × 0.5 hour per area × 0.15 millirem per hour). For the 24 years of the Proposed Action, the total dose to escorts in separate vehicles would, therefore, be about 20 rem (0.38 millirem per shipment × 53,000 shipments). This dose would lead to 0.008 latent cancer fatality in the population of escorts who would be affected. If escorts were required in every population zone for legal-weight truck transport, the total occupational dose would increase by approximately 360 person-rem, or 2.5 percent.

For rail shipments, the analysis assumed that escorts would be 30 meters (98 feet) away from the end of the shipping cask on the nearest railcar. This separation distance is the sum of the:

- Length of a buffer car [about 15 meters (49 feet)] between a cask car and an escort car required by U.S. Department of Transportation regulations [see 49 CFR 174.85(b) and (d), and 49 CFR 174.700(c)],
- Normal separation between cars [a total of about 2 meters (6.6 feet) for two separations],
- Distance from the end of a cask to the end of its rail car [about 5 meters (16 feet)], and

- Assumed average distance from the escort car's near-end to its occupants [5 to 10 meters (16 to 32 feet)].

This analysis assumed that the dose rate at 2 meters (6.6 feet) from the end of the cask car would be 10 millirem per hour, the maximum allowed by U.S. Department of Transportation regulations (49 CFR 173.441). The analysis used these assumptions and the RISKIND computer program to estimate 0.71 millirem per hour as the dose rate in the occupied areas of the escort railcar. For example, an individual escort who occupied the escort car continuously for a 5-day cross-country trip would receive a maximum dose of about 85 millirem. Escorting 26 shipments in a year, this individual would receive a maximum dose of 2.2 rem. Over the 24 years of the Proposed Action, if the same individual escorted 26 shipments every year, he or she would receive a dose of about 53 rem. However, DOE would control worker exposure through administrative procedures (see DIRS 156764-DOE 1999, Article 211). Actual worker exposure would likely be 2 rem per year, or a maximum of 48 rem over 24 years. The use of the dose-to-risk conversion factors recommended by the International Commission on Radiation Protection (DIRS 101836-ICRP 1991, p. 22) projects this dose to increase the potential for the individual to contract a fatal cancer from about 23 percent (DIRS 153066-Murphy 2000, p. 5) to 25 percent. If escorts were required in every population zone, the total occupational dose could increase by as much as 1,000 person-rem, or 30 percent.

J.2.4.3.1 *Radiological Impacts of Accidents*

The analysis of risks from accidents during heavy-haul truck, rail, and legal-weight truck transport of spent nuclear fuel and high-level radioactive waste used the RADTRAN 5 computer code (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) in conjunction with an Access database and the analysis approach discussed in Section J.1.4.2. The analysis of risks due to barging used the same methodology with the exception of conditional probabilities. For barge shipments, the conditional accident probabilities and release fractions (Table J-31) for each cask response category were based on a review of other barge accident analyses.

The definitions of the accident severities listed in Table J-31 are based on the analyses reported in DIRS 152476-Sprung et al. (2000, pp. 7-75 to 7-76). DOE used the same accident severity category definitions as those used in the rail analysis described in Section J.1.4.2. If radioactive material was shipped by barge, both water and land contamination would be possible. Based on a review of Coast Guard accident data files, most barges stay afloat following a collision, justifying the assumption that there would be an airborne plume from a severe barge accident. Furthermore, severity categories 3 through 6 involve fires, which are possible because many barges do not sink after an accident. DIRS 104784-Ostmeyer (1986, all) analyzed the potential importance of water pathway contamination for a spent nuclear fuel transportation accident risk using a "worst-case" water contamination scenario. The analysis showed that the impacts of the water contamination scenario would be about one-fiftieth of the impacts of a comparable accident on land. Therefore, the analysis assumed that deposition would occur over land, not water. DOE used population distributions developed from 1990 Census data to calculate route-specific collective doses. Table J-32 lists the total accident risk for mostly rail case heavy-haul truck scenario, the mostly rail case barge scenario, and the mostly truck scenario.

Impact Speed					
Impact speed exceeds 120 mph	1[a] Seal Failure: Impact (Part) 6.0 × 10^{-7}[(b)] (Ru) 6.0 × 10^{-7} (Cs) 2.4 × 10^{-8} (Kr) 8.0 × 10^{-1} (Crud) 2.0 × 10^{-3} Prob 1.53 × 10^{-8}[(c)]	11 Seal Failure: Impact (Part) 6.1 × 10^{-7} (Ru) 6.1 × 10^{-7} (Cs) 2.4 × 10^{-8} (Kr) 8.2 × 10^{-1} (Crud) 2.0 × 10^{-3} Prob 1.44 × 10^{-10}	12 Seal Failure: Impact (Part) 6.7 × 10^{-7} (Ru) 6.7 × 10^{-7} (Cs) 2.7 × 10^{-8} (Kr) 8.9 × 10^{-1} (Crud) 2.2 × 10^{-3} Prob 1.02 × 10^{-12}	13 Seal Failure: Impact (Part) 6.8 × 10^{-7} (Ru) 6.8 × 10^{-7} (Cs) 5.9 × 10^{-6} (Kr) 9.1 × 10^{-1} (Crud) 2.5 × 10^{-3} Prob 0	17 Shear/Puncture; Seal Failure by Fire (Part) 6.8 × 10^{-7} (Ru) 6.4 × 10^{-6} (Cs) 5.9 × 10^{-6} (Kr) 9.1 × 10^{-1} (Crud) 3.3 × 10^{-3} Prob 0
Impact speed from 90 to 120 mph		8 Seal Failure by Fire (Part) 6.1 × 10^{-7} (Ru) 6.1 × 10^{-7} (Cs) 2.4 × 10^{-8} (Kr) 8.2 × 10^{-1} (Crud) 2.0 × 10^{-3} Prob 1.13 × 10^{-8}	9 Seal Failure by Fire (Part) 6.7 × 10^{-7} (Ru) 6.7 × 10^{-7} (Cs) 2.7 × 10^{-8} (Kr) 8.9 × 10^{-1} (Crud) 2.2 × 10^{-3} Prob 8.03 × 10^{-11}	10 Seal Failure by Fire (Part) 6.8 × 10^{-7} (Ru) 6.8 × 10^{-7} (Cs) 5.9 × 10^{-6} (Kr) 9.1 × 10^{-1} (Crud) 2.5 × 10^{-3} Prob 0	16 Shear/Puncture; Seal Failure by Fire (Part) 6.8 × 10^{-7} (Ru) 6.4 × 10^{-6} (Cs) 5.9 × 10^{-6} (Kr) 9.1 × 10^{-1} (Crud) 3.3 × 10^{-3} Prob 0
Impact speed from 60 to 90 mph		5 Seal Failure by Fire (Part) 3.2 × 10^{-7} (Ru) 3.2 × 10^{-7} (Cs) 1.3 × 10^{-8} (Kr) 4.3 × 10^{-1} (Crud) 1.8 × 10^{-3} Prob 4.65 × 10^{-7}	6 Seal Failure by Fire (Part) 3.7 × 10^{-7} (Ru) 3.7 × 10^{-7} (Cs) 1.5 × 10^{-8} (Kr) 4.9 × 10^{-1} (Crud) 2.1 × 10^{-3} Prob 3.31 × 10^{-9}	7 Seal Failure by Fire (Part) 2.1 × 10^{-6} (Ru) 2.1 × 10^{-6} (Cs) 2.7 × 10^{-5} (Kr) 8.5 × 10^{-1} (Crud) 3.1 × 10^{-3} Prob 0	15 Shear/Puncture; Seal Failure by Fire (Part) 9.0 × 10^{-6} (Ru) 5.0 × 10^{-5} (Cs) 5.5 × 10^{-5} (Kr) 8.5 × 10^{-1} (Crud) 5.9 × 10^{-3} Prob 0
Impact speed from 30 to 60 mph		2 Seal Failure by Fire (Part) 1.0 × 10^{-7} (Ru) 1.0 × 10^{-7} (Cs) 4.1 × 10^{-9} (Kr) 1.4 × 10^{-1} (Crud) 1.4 × 10^{-3} Prob 5.88 × 10^{-5}	3 Seal Failure by Fire (Part) 1.3 × 10^{-7} (Ru) 1.3 × 10^{-7} (Cs) 5.4 × 10^{-9} (Kr) 1.8 × 10^{-1} (Crud) 1.8 × 10^{-3} Prob 1.81 × 10^{-6}	4 Seal Failure by Fire (Part) 3.8 × 10^{-6} (Ru) 3.8 × 10^{-6} (Cs) 3.6 × 10^{-5} (Kr) 8.4 × 10^{-1} (Crud) 3.2 × 10^{-3} Prob 7.49 × 10^{-8}	14 Shear/Puncture; Seal Failure by Fire (Part) 1.8 × 10^{-5} (Ru) 8.4 × 10^{-5} (Cs) 9.6 × 10^{-5} (Kr) 8.4 × 10^{-1} (Crud) 6.4 × 10^{-3} Prob 7.49 × 10^{-11}
No Impact	19 No Releases Prob 0.99993			18 Seal Failure by Fire (Part) 6.7 × 10^{-8} (Ru) 6.7 × 10^{-8} (Cs) 1.7 × 10^{-5} (Kr) 8.4 × 10^{-1} (Crud) 2.5 × 10^{-3} Prob 5.86 × 10^{-6}	
	No Fire	*End temperature: ambient to 350°C (662°F)*	*End temperature: 350°C to 750°C (662°F to 1,382°F)*	*End temperature: 750°C to 1,000°C (1,382°F to 1,832°F)*	*End temperature: 750°C to 1,000°C (1,382°F to 1,832°F)*

Cask Temperature in Fire

a. The numbers at the top of each cell refer to an accident scenario (called a case) in DIRS 152476-Sprung et al. (2000, p. 7-74).

b. (Part) is the release fraction for particulates; (Ru) is the release fraction for ruthenium; (Cs) is the release fraction for volatiles; (Kr) is the release fraction for gas; (Crud) is the release fraction for crud. The numbers next to them are the fraction that would be released in the accident.

c. The conditional probability that, if there was an accident, the particular cell would describe the accident scenario.

Figure J-8a. Impact speed and temperature matrix for pressurized-water reactor spent nuclear fuel in a steel-depleted uranium-steel truck cask.

Impact Speed					
Impact speed exceeds 120 mph	3[a] Seal Failure by Impact (Part) 1.9×10^{-5}[(b)] (Ru) 1.9×10^{-5} (Cs) 1.8×10^{-5} (Kr) 8.0×10^{-1} (Crud) 6.4×10^{-2} Prob 4.49×10^{-9}[(c)]	13 Seal Failure by Impact (Part) 2.0×10^{-5} (Ru) 2.0×10^{-5} (Cs) 1.8×10^{-5} (Kr) 8.2×10^{-1} (Crud) 6.5×10^{-2} Prob 3.70×10^{-11}	14 Seal Failure by Impact (Part) 2.1×10^{-5} (Ru) 2.1×10^{-5} (Cs) 2.0×10^{-5} (Kr) 8.9×10^{-1} (Crud) 7.1×10^{-2} Prob 1.03×10^{-12}	15 Seal Failure by Impact (Part) 2.2×10^{-5} (Ru) 2.2×10^{-5} (Cs) 2.2×10^{-5} (Kr) 9.1×10^{-1} (Crud) 7.4×10^{-2} Prob 1.37×10^{-13}	19 Shear/Puncture; Seal Failure by Fire (Part) 2.2×10^{-5} (Ru) 2.3×10^{-5} (Cs) 2.2×10^{-5} (Kr) 9.1×10^{-1} (Crud) 7.4×10^{-2} Prob 1.37×10^{-16}
Impact speed from 90 to 120 mph	2 Seal Failure by Impact (Part) 1.3×10^{-5} (Ru) 1.3×10^{-5} (Cs) 8.6×10^{-6} (Kr) 8.0×10^{-1} (Crud) 4.4×10^{-2} Prob 5.68×10^{-7}	10 Seal Failure by Impact (Part) 1.3×10^{-5} (Ru) 1.3×10^{-5} (Cs) 8.8×10^{-6} (Kr) 8.2×10^{-1} (Crud) 4.5×10^{-2} Prob 4.68×10^{-9}	11 Seal Failure by Impact (Part) 1.5×10^{-5} (Ru) 1.5×10^{-5} (Cs) 9.6×10^{-6} (Kr) 8.9×10^{-1} (Crud) 4.9×10^{-2} Prob 1.31×10^{-10}	12 Seal Failure by Impact (Part) 1.5×10^{-5} (Ru) 1.5×10^{-5} (Cs) 1.4×10^{-5} (Kr) 9.1×10^{-1} (Crud) 5.1×10^{-2} Prob 1.74×10^{-11}	18 Shear/Puncture; Seal Failure by Fire (Part) 1.5×10^{-5} (Ru) 1.8×10^{-5} (Cs) 1.4×10^{-5} (Kr) 9.1×10^{-1} (Crud) 5.1×10^{-2} Prob 1.74×10^{-14}
Impact speed from 60 to 90 mph	1 Seal Failure by Impact (Part) 2.5×10^{-7} (Ru) 2.5×10^{-7} (Cs) 1.2×10^{-8} (Kr) 4.1×10^{-1} (Crud) 1.4×10^{-3} Prob 8.20×10^{-6}	7 Seal Failure by Impact (Part) 2.6×10^{-7} (Ru) 2.6×10^{-7} (Cs) 1.3×10^{-8} (Kr) 4.3×10^{-1} (Crud) 1.5×10^{-3} Prob 6.76×10^{-8}	8 Seal Failure by Impact (Part) 2.9×10^{-7} (Ru) 2.9×10^{-7} (Cs) 1.5×10^{-8} (Kr) 4.9×10^{-1} (Crud) 1.7×10^{-3} Prob 1.88×10^{-9}	9 Seal Failure by Impact (Part) 6.8×10^{-6} (Ru) 6.8×10^{-6} (Cs) 2.7×10^{-5} (Kr) 8.5×10^{-1} (Crud) 4.5×10^{-3} Prob 2.51×10^{-10}	17 Shear/Puncture; Seal Failure by Fire (Part) 8.9×10^{-5} (Ru) 5.0×10^{-5} (Cs) 5.5×10^{-5} (Kr) 8.5×10^{-5} (Crud) 5.4×10^{-5} Prob 2.51×10^{-5}
Impact speed from 30 to 60 mph		4 Seal Failure by Fire (Part) 1.0×10^{-7} (Ru) 1.0×10^{-7} (Cs) 4.1×10^{-9} (Kr) 1.4×10^{-1} (Crud) 1.4×10^{-3} Prob 2.96×10^{-5}	5 Seal Failure by Fire (Part) 1.3×10^{-7} (Ru) 1.3×10^{-7} (Cs) 5.4×10^{-9} (Kr) 1.8×10^{-1} (Crud) 1.8×10^{-3} Prob 8.24×10^{-7}	6 Seal Failure by Fire (Part) 1.4×10^{-5} (Ru) 1.4×10^{-5} (Cs) 3.6×10^{-5} (Kr) 8.4×10^{-1} (Crud) 5.4×10^{-3} Prob 1.10×10^{-7}	16 Shear/Puncture; Seal Failure by Fire (Part) 1.8×10^{-5} (Ru) 8.4×10^{-5} (Cs) 9.6×10^{-5} (Kr) 8.4×10^{-1} (Crud) 6.4×10^{-3} Prob 4.15×10^{-11}
No Impact	21 No Release Prob 0.99996			20 Seal Failure by Fire (Part) 2.5×10^{-7} (Ru) 2.5×10^{-7} (Cs) 1.7×10^{-5} (Kr) 8.4×10^{-1} (Crud) 9.4×10^{-3} Prob 4.91×10^{-5}	
	No Fire	*End temperature: ambient to 350°C (662°F)*	*End temperature: 350°C to 750°C (662°F to 1,382°F)*	*End temperature: 750°C to 1,000°C (1,382°F to 1,832°F)*	*End temperature: 750°C to 1,000°C (1,382°F to 1,832°F)*

Cask Temperature in Fire

a. The numbers at the top of each cell refer to an accident scenario (called a case) in DIRS 152576-Sprung et al. (2000, p. 7-76).
b. (Part) is the release fraction for particulates; (Ru) is the release fraction for ruthenium; (Cs) is the release fraction for volatiles; (Kr) is the release fraction for gas; (Crud) is the release fraction for crud. The numbers next to them are the fraction that would be released in the accident.
c. The conditional probability that, if there is an accident, the particular cell will describe the accident scenario.

Figure J-8b. Impact speed and temperature matrix for pressurized-water reactor spent nuclear fuel in a steel-lead-steel rail cask.

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Table J-31. Release fractions and conditional probabilities for spent nuclear fuel transported by barge.

Severity category	Case	Conditional probability	Release fractions (pressurized-water reactor/boiling-water reactor)				
			Krypton	Cesium	Ruthenium	Particulates	Crud
1	21	0.994427	0.0	0.0	0.0	0.0	0.0
2	1, 4, 5, 7, 8	5.00×10^{-3}	$1.96 \times 10^{-1}/2.35 \times 10^{-2}$	$5.87 \times 10^{-9}/7.04 \times 10^{-10}$	$1.34 \times 10^{-7}/1.47 \times 10^{-8}$	$1.34 \times 10^{-7}/1.47 \times 10^{-8}$	$1.37 \times 10^{-3}/5.59 \times 10^{-4}$
3	20	5.00×10^{-6}	$8.39 \times 10^{-1}/8.39 \times 10^{-1}$	$1.68 \times 10^{-5}/1.68 \times 10^{-5}$	$2.52 \times 10^{-7}/2.52 \times 10^{-7}$	$2.52 \times 10^{-7}/2.52 \times 10^{-7}$	$9.44 \times 10^{-3}/9.44 \times 10^{-2}$
4	2, 3, 10	5.00×10^{-4}	$8.00 \times 10^{-1}/8.00 \times 10^{-1}$	$8.71 \times 10^{-6}/8.71 \times 10^{-6}$	$1.32 \times 10^{-5}/1.32 \times 10^{-5}$	$1.32 \times 10^{-5}/1.32 \times 10^{-5}$	$4.42 \times 10^{-3}/4.42 \times 10^{-2}$
5	6	0.0	$8.35 \times 10^{-1}/8.37 \times 10^{-1}$	$3.60 \times 10^{-5}/4.12 \times 10^{-5}$	$1.37 \times 10^{-5}/1.82 \times 10^{-5}$	$1.37 \times 10^{-5}/1.82 \times 10^{-5}$	$5.36 \times 10^{-3}/5.43 \times 10^{-3}$
6	9,11,12,13,14,15,16, 17,18,19	1.30×10^{-6}	$8.47 \times 10^{-1}/8.45 \times 10^{-1}$	$5.71 \times 10^{-5}/7.30 \times 10^{-5}$	$4.63 \times 10^{-5}/5.94 \times 10^{-5}$	$1.43 \times 10^{-5}/1.96 \times 10^{-5}$	$1.59 \times 10^{-2}/1.60 \times 10^{-2}$

Table J-32. Comparison of accident risks for the mostly rail heavy-haul truck and barge shipping scenarios.[a]

Category	Mostly rail (heavy-haul option–24 sites)	Mostly rail (barge option–17 of 24 heavy-haul sites)	Mostly truck
Population dose (person-rem)	0.89	1.5	0.5
Estimated LCFs[b]	0.00045	0.001	0.0002
Traffic fatalities[c]	2.7	2.7	4.5

a. Impacts are totals over 24 years.
b. LCF = latent cancer fatality.
c. Traffic fatality impacts for mostly rail scenarios are averages of range of estimated traffic fatality impacts (2.3 to 3.1) for national transportation for the Proposed Action.

Excerpt from Section J.3.3.1

2. *Aircraft Crash Accident.* Two of the three intermodal transfer station locations are near airports that handle large volumes of air traffic. The Apex/Dry Lake location is about 16 kilometers (10 miles) northeast of the Nellis Air Force Base runways. Between 60,000 and 67,000 takeoffs and landings occur at Nellis Air Force Base each year (DIRS 148083-Luedke 1997, all). The Sloan/Jean intermodal transfer area begins about 16 kilometers southwest of McCarran International Airport in Las Vegas. In 1996, McCarran had an average of 1,300 daily aircraft operations (DIRS 104725-Best 1998, all). Because of the large number of aircraft operations at these airports, the probability of an aircraft crash on the proposed intermodal transfer station could be within the credible range. To assess the consequences of an aircraft crash, an analysis evaluated the ability of large aircraft parts to penetrate the shipping casks. The parts with the highest chance of penetration are the jet engines and jet engine shafts (DIRS 101810-DOE 1996, p. 58). The analysis used a recommended formula (DIRS 101810-DOE 1996, p. 69) for predicting the penetration of steel targets, as follows:

$$T^{1.5} = 0.5 \times M \times V^2 \div 17{,}400 \times K_s \times D^{1.5}$$

where:

- T = predicted thickness to just perforate a steel plate (inches)
- M = projectile mass (weight/gravitational acceleration)
- V = projectile impact velocity (feet per second)
- K_s = constant depending on the grade of steel (usually about 1.0)
- D = projectile diameter (inches)

The primary jet aircraft operating at Nellis Air Force Base are the F-15 and F-16 high-performance fighters, which represent more than 70 percent of Base aircraft operations (DIRS 103472-USAF 1999, pp. 1-34 and 1-35). Because both of these aircraft use the same engine (DIRS 156757-Morissette 2001, p. 1), DOE selected that engine as the military aircraft engine for the penetration analysis. For the commercial aircraft penetration analysis, DOE selected the B-767, a large widely used commercial jet. Table J-52 lists the engine characteristics for these aircraft.

Table J-52. Aircraft engine projectile characteristics.[a]

Aircraft	Engine weight (kilograms)[b]	Engine diameter (centimeters)[c]	Engine shaft weight (kilograms)[b]	Engine shaft diameter (centimeters)[c]
F-15, 16	1,900	91	25	7.6
B-767	4,500	240	110	15

a. Source: DIRS 156757-Morissette (2001, all).
b. To convert kilograms to pounds, multiply by 2.2046.
c. To convert centimeters to inches, multiply by 0.3937.

The velocity selected for the penetration analysis was 500 feet per second (550 kilometers or 340 miles per hour). This velocity is based on the discussion in DIRS 101810-DOE (1996, p. C-7 that indicates that impact velocities would typically be less than 500 feet per second. Because the selected intermodal transfer station would be near airports, anticipated aircraft velocities would be less because operations would involve takeoffs and landings using lower speeds. Thus, the selection of 500 feet per second for the impact velocity is conservative.

The results in Table J-53 indicate that none of the aircraft projectiles considered would penetrate the shipping casks, which would have steel walls about 18 centimeters (7 inches) thick (DIRS 101837-JAI 1996, all).

Table J-53. Results of aircraft projectile penetration analysis.[a]

Projectile	Penetration thickness (centimeters)[a]
F-15, 16 engine	6.7
F-15, 16 engine shaft	4.5
B-757 engine	4.7
B-757 engine shaft	6.3

a. To convert centimeters to inches, multiply by 0.3937.

This evaluation found no credible accidents with the potential for radioactive release at an intermodal transfer station. In a separate analysis performed following the events of September 11, 2001, Bechtel SAIC Company, LLC analysts reached a similar conclusion that the impact of large and small missiles produced during an aircraft crash would not perforate or crack a cask (DIRS 157210-BSC 2001, p. iii). However, the analysis did not preclude the potential for the impact and resultant fire to cause seal failure. The consequences of such an event would be less than 0.65 latent cancer fatality if the crash occurred in an urban area (DIRS 157210-BSC 2001, all).

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101483	Yuan et al. 1995	Yuan, Y.C.; Chen, S.Y.; Biwer, B.M.; and LePoire, D.J. 1995. *RISKIND –A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel.* ANL/EAD-1. Argonne, Illinois: Argonne National Laboratory. TIC: 241380.

CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor		
exa-	E	1,000,000,000,000,000,000	=	10^{18}
peta-	P	1,000,000,000,000,000	=	10^{15}
tera-	T	1,000,000,000,000	=	10^{12}
giga-	G	1,000,000,000	=	10^{9}
mega-	M	1,000,000	=	10^{6}
kilo-	k	1,000	=	10^{3}
deca-	D	10	=	10^{1}
deci-	d	0.1	=	10^{-1}
centi-	c	0.01	=	10^{-2}
milli-	m	0.001	=	10^{-3}
micro-	µ	0.000 001	=	10^{-6}
nano-	n	0.000 000 001	=	10^{-9}
pico-	p	0.000 000 000 001	=	10^{-12}