SECOND REPORT TO

THE U.S. CONGRESS

AND

THE U.S. SECRETARY OF ENERGY

FROM THE

NUCLEAR WASTE TECHNICAL REVIEW BOARD

November 1990

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UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
1100 Wilson Boulevard, Suite 910
Arlington, VA 22209

November 27, 1990

The Honorable Thomas S. Foley
Speaker of the House
United States House of Representatives
H-204 Capitol
Washington, D.C. 20515-6501

The Honorable Robert C. Byrd
President Pro Tempore
United States Senate
Hart Office Building, Suite 311
Washington, D.C. 20510-1902

The Honorable James D. Watkins
U.S. Secretary of Energy
U.S. Department of Energy
Forrestal Building
Washington, D.C. 20585

Dear Speaker Foley, Senator Byrd, and Secretary Watkins:

The Nuclear Waste Technical Review Board (Board) herewith submits its second report as required by the Nuclear Waste Policy Amendments Act of 1987, Public Law 100-203.

Congress created the Board to evaluate the scientific and technical validity of activities undertaken by the Department of Energy (DOE) in its civilian high-level nuclear waste disposal program. The Board is charged with evaluating the DOE's characterization of Yucca Mountain as a potential location for a repository for the permanent disposal of high-level radioactive waste (HLW). The Board also will evaluate activities relating to the packaging and transportation of HLW.

During the seven months since its *First Report*, the Board pursued the issues it outlined in that report as planned future activities. To do this, the Board continued interactions with the DOE, listened to assessments of the DOE's site-characterization efforts by the State of Nevada and others, and obtained and reviewed technical and scientific information on the DOE's program.

In this report the Board evaluates its interactions with the DOE and other organizations. It also assesses information from other sources and comments on recent developments at the DOE.

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At this time, the Board has no specific recommendations that require congressional action. It does, however, make a number of recommendations regarding the DOE program for radioactive waste management that are intended to improve ongoing technical work.

We thank you for this opportunity to serve the nation and Congress. As our work progresses, we hope to assist Congress and the DOE in furthering the goal of safe, efficient, and timely disposal of civilian high-level radioactive waste.

Sincerely,

Don U. Deere, Chairman

Clarence R. Allen

John E. Cantlon

Melvin W. Carter

Patrick A. Domenico

Donald Langmuir

D. Warner North

Dennis L. Price

Ellis D. Verink

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Executive Summary

In 1982, Congress passed the Nuclear Waste Policy Act, which, along with its amendments, provides the framework for the nation's program for the disposal of civilian high-level radioactive waste.* The Department of Energy (DOE) is charged with managing the permanent disposal of high-level radioactive waste. The 1987 amendments designated a site at Yucca Mountain, Nevada, as the sole site to be characterized for potential suitability as a mined geologic repository. The amendments also created the Nuclear Waste Technical Review Board (the Board) to evaluate the scientific and technical validity of the DOE's activities to characterize Yucca Mountain as a potential site for such a repository, as well as activities related to packaging and transporting high-level waste.

A. Board Activities

The Nuclear Waste Technical Review Board, whose first eight members were appointed in January 1989 by President Reagan, met for the first time in March 1989 and published its *First Report to the U.S. Congress and the U.S. Secretary of Energy* in March 1990 (NWTRB 1990). The *First Report* reviewed the Board's activities during its first 10 months. This second report summarizes the Board's activities from January 1 to July 31, 1990. As in its first year, the Board conducted its evaluation through discussions; briefings to both the full Board and its panels by DOE representatives and others; reviews of DOE's Site Characterization Plan (DOE 1988) and other DOE studies; review of selected literature by individual members and staff; and through participation in field trips. Four Board meetings were held: on March 2-3 in Tucson, Arizona; on March 22 in Washington, D.C.; on April 7-8 in Las Vegas, Nevada; and on July 23 and 26 in Atlanta, Georgia.

In addition, members attended 10 Board-sponsored panel meetings and technical exchanges with representatives from the DOE and its contractors, the Nuclear Regulatory Commission (NRC), and the Environmental Protection Agency (EPA). They also met with representatives of the State of Nevada, the Western Shoshone National Council, the Soil Conservation Service, the National Park Service, the Fish and Wildlife Service, the U.S. Geological Survey, and the utilities. Furthermore, members and staff attended a variety of related technical conferences, symposia, and workshops and met with nuclear waste disposal experts in Sweden and the Federal Republic of Germany during a week-long trip.

In March, as a result of a careful review of the issues, the Containers and Transportation Panel was split into two new panels: the Engineered Barrier System Panel and the Transportation Panel, which later was renamed the Transportation & Systems Panel. An additional panel, the Quality Assurance Panel, also was created.

On April 19, 1990, the terms of three Board members expired. Two members were reappointed by President Bush to serve until April 19, 1994. The third

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member's reappointment should be finalized in November. On May 31, 1990, President Bush also appointed a new member, the Board's first hydrogeologist, bringing the total membership to nine; the Board's parent legislation authorizes a total of eleven members.

B. Recommendations

During the past seven months of reviewing the DOE's activities, the Board focused on the high-priority issues that it feels are important for early determination of the Yucca Mountain Site's suitability for repository development. Specific areas of inquiry and recommendations are discussed in Chapter 2 of this report. The 20 recommendations, which were developed within the framework of individual panel activities, cover a wide range of topics. To facilitate their presentation here, they have been grouped into seven broad areas and summarized.

Effects of seismicity and faulting on facility design and site suitability

In these recommendations to the DOE, the Board addresses how potential seismic and faulting risks should be considered in determining site suitability and developing criteria for facility design.

1. Increased emphasis should be placed on understanding the engineering, public safety, and environmental consequences of seismic events at Yucca Mountain, including earthquakes of magnitudes larger than those that are likely to occur during the lifetime of the facility.

2. Discussions of site suitability should be based on the likelihood of adverse consequences and not on the occurrence of earthquake ground motion or fault displacement alone.

3. Formulation of a specific tectonic model, acceptable with a high degree of confidence, should not be viewed as a prerequisite to site suitability or to ensuring public safety and environmental protection.

4. Geologic licensing criteria and standards for the repository and its surface facilities should reflect the nature and relative vulnerability of the repository complex and the problems it poses. The criteria and standards should ensure public safety and environmental protection in the light of current scientific knowledge and engineering practice, including the feasible mitigation of adverse consequences.

Testing for site suitability

The following Board recommendations on proposed geologic tests are made so that site suitability can be evaluated by the DOE as early as possible.

5. Planned scientific testing of the Yucca Mountain geologic block should be re-evaluated to give highest priority to those tests and studies that provide the data essential to assess the suitability of the site. Each proposed study should be evaluated in terms of procedures, technologies, test locations, and appropriateness in meeting stated objectives.

6. The DOE should consider expanding its development program for dry-drilling equipment to include the capability to drill inclined holes.

Performance assessment

In these recommendations to the DOE, the Board addresses methodologies and alternative approaches that can be used for assessing repository performance.

7. The DOE should continue using decision-aiding methodology to provide more explicit and formal means for relating program decisions to risk and performance issues. Such methods should be used in an iterative and ongoing fashion to explain the reasoning behind major programmatic decisions before these decisions are committed. The four existing DOE task force studies applying these methods should be closely coordinated.

8. The DOE should continue to develop methods for assessing expert judgment in areas of significant uncertainty. Furthermore, the DOE should incorporate into the current task force studies the views of technical experts *outside* the DOE and its contractors. The basis for each expert judgment needs to be carefully documented.

9. The DOE should consider investigating more extensively the use of natural analogues to support performance assessment for a potential repository at the Yucca Mountain Site.

Long-lived waste packages

These Board recommendations stress the importance of using long-lived waste packages as a means of ensuring repository performance.

10. At a future meeting, the DOE should respond to the Engineered Barrier System (EBS) Panel's four questions of January 6, 1990, relating to EBS performance. It should be emphasized that the Board's interest in a robust, extended-life EBS does not imply a diminished interest in the geologic barriers' contribution to overall repository performance; rather, the Board is suggesting engineered barriers may reduce the adverse consequences associated with difficult-to-predict geologic or climatological events occur.

11. A workshop should be held to investigate the practicality, advantages, and disadvantages of developing a robust, extended-life EBS that would contribute to containment for periods of time well beyond 1,000 years. The Board would be pleased to assist in developing an agenda for such a workshop.

Waste container materials, configurations, and disposal environments

These Board recommendations to the DOE pertain to evaluating further a number of options on waste package design.

12. Studies of alternative materials should be restarted. These studies should include evaluation of container materials and designs, emplacement designs, and container configurations, including both internal adsorbing materials and external back-fill materials.

13. Heater tests should be reinitiated. These tests should examine the effects of alternative emplacement orientations and three-dimensional and multiple heat sources for a range of thermal loads.

14. The EBS development and testing program should be coordinated and funded at a level sufficient to produce a statistical basis for assessing its contribution to long-term predictions of repository behavior. Tests should be long-term—preferably exceeding five years—and include both laboratory and field testing.

Coordination and integration of environmental studies

These Board recommendations pertain to the need for the environmental study program at Yucca Mountain to be coordinated with respect to the various stakeholders involved and integrated with respect to the different subject areas of investigation.

15. The DOE should continue to include in its study plans the interests and concerns of Native Americans, the States of California and Nevada, the National Park Service, the Soil Conservation Service, and the Fish and Wildlife Service.

16. The DOE and the State of Nevada should explore the possibility of initiating a cooperative program to develop baseline environmental information.

17. All environmental programs at the Yucca Mountain Site funded by the Nuclear Waste Fund should be developed and conducted in a manner that the data obtained are appropriate to and can be used during licensing.

18. An integrated environmental program that takes cognizance of ecosystem processes should be developed for the Yucca Mountain Site. The results of this program should permit assessment of the effects of site characterization and repository construction and operation on the local ecosystem. The program also should provide a basis for understanding ecologic pathways for any radioactive materials that might escape containment during repository construction, operation, and decommissioning.

Human factors and system safety in transportation and handling of spent fuel

These Board recommendations pertain to enhancing the safety of spent fuel transportation when the scale of future transport activities becomes significantly larger.

19. The NRC should develop policy statements, program guidelines, and, if feasible, criteria documents in human factors and system safety engineering that will help ensure that the DOE's and utilities' system acquisition programs address future accident potentials. The goal should be for the system acquisition programs to be complete in all the technologies that can contribute to operational safety and efficiency, including emergency and mitigation planning.

20. Priority should be placed on developing a high-level waste management system that minimizes the handling of spent fuel.

C. Concluding Perspectives

In general, the Board is pleased with the DOE's efforts to address issues and concerns that the Board has raised. The Board looks forward to working with Dr. Bartlett and the recently reorganized OCRWM program within the DOE. Because of the DOE's responsiveness to Board requests, the Board has been able to familiarize itself with many aspects of the DOE program over the past months. The DOE has made a good-faith effort to address the recommendations in the Board's *First Report*. However, the ultimate results of these efforts can be judged only over time. The Board will continue to monitor ongoing DOE activities in these areas and in other areas identified as potentially problematic.

The Board sees progress and renewed commitment by the DOE to carry forward its mandated responsibilities in investigating the suitability of the Yucca Mountain Site for a permanent repository. In recent testimony before the Senate Subcommittee on Nuclear Regulation, Committee on Environment and Public Works, the Board expressed its opinions on the DOE's progress and outlined Board concerns about issues that could impede further progress.

One critical problem involves the DOE's impasse with the State of Nevada over access to the Yucca Mountain Site. Progress of the DOE site-characterization activities at the Yucca Mountain Site depend directly on receiving the necessary state permits to allow access to the site. Ongoing litigation between the State of Nevada and the DOE has delayed site characterization with the inevitable increase in costs. The Board is concerned about further delays in site-characterization activities.

Several other recent developments may affect the DOE's program. The EPA and the NRC are currently re-evaluating their respective standards and regulations involving the disposal of radioactive waste. In July 1990, the National Research Council's Board on Radioactive Waste Management issued a report on a conference in 1988 attended by physical scientists, engineers, political scientists, and other experts familiar with issues related to radioactive waste disposal. The report advocates an approach that is less prescriptive and more accommodating to new insights, unexpected information, and changing circumstances. The development by the DOE of a licensing support system (LSS), a giant database system being designed to help the NRC handle the more than 25 million pages required for licensing a repository, is proceeding. The Board looks forward to becoming a full participant in the LSS. Finally, the Board welcomes the appointment of David H. Leroy to the position of nuclear waste negotiator. It will be his responsibility to work with governors, Native Americans, and others to find a willing host state for a monitored retrievable storage facility and possibly for a repository.

As part of its ongoing evaluation of the technical validity of DOE activities, the Nuclear Waste Technical Review Board scheduled a series of public hearings for the fall. A public hearing on radioactive waste transportation issues was held in August in Nye County, Nevada (the location of the Yucca Mountain Site), and two hearings—on the possible environmental and public health effects of site characterization, repository development, and operation and on transportation issues—were held in Reno, Nevada, in October 1990. The Board hopes that the public hearings will encourage a variety of persons and groups who are interested in the DOE program to express their concerns. Additionally, the Board

held meetings in October with the DOE on the prioritization of surface-based testing; socioeconomic issues relating to characterizing, constructing, and operating a repository; and transportation. Meetings on quality assurance and transportation issues are set for November, and panel meetings for the coming year are being scheduled. The Board also will continue to gather information on foreign programs with potential applicability to the U.S. waste management program.

As the nation's radioactive waste management program proceeds, all of the participants will face a variety of important technical, ethical, political, and socioeconomic challenges. The Nuclear Waste Technical Review Board will continue to fulfill its congressionally mandated responsibilities as part of this critical undertaking.

Introduction

In 1982, Congress passed the Nuclear Waste Policy Act (NWPA), which assigned to the Department of Energy (DOE) the responsibility for managing the final disposal of the nation's civilian high-level radioactive waste.* Within the NWPA, Congress established the DOE Office of Civilian Radioactive Waste Management (OCRWM) to carry out the process of high-level waste disposal. To support the DOE program for managing the disposal of civilian high-level waste, Congress created the Nuclear Waste Fund by placing a fee on nuclear-produced electrical power.

In 1987, Congress passed further legislation amending the NWPA, known as the Nuclear Waste Policy Amendments Act (NWPAA) of 1987. This legislation designated a site at Yucca Mountain, Nevada (Yucca Mountain Site), as the sole site to be characterized for its suitability for locating a repository to hold the waste. The site, in Nye County, Nevada, about 100 miles northwest of Las Vegas in the Great Basin, includes land areas controlled by (1) the Bureau of Land Management, the Department of the Interior, (2) Nellis Air Force Range, the Department of Defense, and (3) the Nevada Test Site, the Department of Energy.

The NWPA and its amendments also provide the legislative framework under which the DOE must operate when evaluating potential sites for the disposal of high-level waste. Additionally, the DOE must comply with regulations published by the Nuclear Regulatory Commission (NRC) and standards promulgated by the Environmental Protection Agency (EPA). The DOE also operates under its own regulations. If it determines that the Yucca Mountain Site is suitable, the DOE must then demonstrate to the NRC that the site meets licensing regulations and guidelines. These regulations and guidelines are intended to protect the health and safety of the public and to minimize potential environmental effects.

When a site has been found suitable and the repository completed, it will provide for the permanent disposal of spent nuclear fuel from more than 100 nuclear power plants located at 70 sites throughout the United States. It is expected that these plants will produce approximately 87,000 metric tons of spent nuclear fuel during their lifetime (DOE 1989, Energy Information Administration, ix). Approximately 8,000 metric tons of defense high-level radioactive waste from reprocessing also is expected to be placed in the repository.

The Nuclear Waste Technical Review Board (Board) was established by the NWPAA of 1987 to evaluate the technical and scientific validity of activities undertaken by the DOE including (1) site characterization and (2) activities relating to the packaging and transportation of high-level radioactive waste. On January 18, 1989, President Reagan appointed eight members to the Board. They were sworn in at the first full Board meeting on March 7-8, 1989. On May 31, 1990, a ninth member was appointed by President Bush. (See Appendix A for a curriculum

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vitae of each member.) The Board currently has seven internal working panels that address the diversity of technical and scientific topics under consideration by the Board. (See Appendix B for a breakdown of panels and panel assignments.) The panels are organized around the following topics: structural geology and geoengineering; hydrogeology and geochemistry; engineered barrier system; transportation and systems; environment and public health; risk and performance analysis; and quality assurance. (See description in Chapter 2.)

The panels report periodically to the full Board on their activities, concerns, and future plans. Included in the panel reports are conclusions and recommendations based on information gathered primarily through panel meetings, technical information exchanges, and informal discussions with experts from the public and private sectors. Each panel report is presented to and reviewed by the full Board and eventually adopted by the Board. Once a panel report is adopted, it becomes part of a broader spectrum of information used by the Board to prepare its reports to Congress and the Secretary of Energy.

In its *First Report to the U.S. Congress and the U.S. Secretary of Energy* published in March 1990 (NWTRB 1990), the Board detailed its charge under the law, the history of legislation controlling repository development, the major areas of concern that it identified in its first 10 months of operation, and its long- and short-term plans. The Board also made a number of recommendations to Congress and the Secretary of Energy on what it identified as "issues of concern."

The second report is a result of Board activities from January 1 to July 31, 1990, including meetings with, among others, representatives of the DOE and its contractors, the NRC, the Western Shoshone National Council, the U.S. Geological Survey, the State of Nevada, the National Park Service, the Soil Conservation Service, the Fish and Wildlife Service, and representatives of the utilities. During its second reporting period, the Board addressed many of the issues it identified in its *First Report*. In some cases, the Board believes it has gained enough insight to be able to make additional recommendations. In others, it simply reports its findings to date and looks forward to further technical review of the DOE's program for the management of civilian radioactive waste.

Chapter 1
Background

High-level radioactive waste has never been disposed of permanently in a mined geologic repository anywhere in the world. Disposal is a complex undertaking, which poses scientific and technical challenges in diverse areas, such as designing the repository system and assessing the geologic and engineered barriers to radionuclide migration, coping with inevitable uncertainties of natural and physical phenomena involved in the long-term performance of a repository, setting standards to protect public health and the environment, and managing the entire process, including final decommissioning.

In its *First Report* (NWTRB 1990), the Board identified many areas of concern involved with site characterization and repository development that require technical investigation or resolution. The Board also made a number of recommendations to the DOE in some of these areas and considered subjects that the Board wished to explore further. That report also contained a number of general observations about the nuclear waste management program that continue to apply. This chapter summarizes these observations and gives an update on Board activities.

A. Existing Framework for Repository Development

Mined geologic repositories consist of natural geologic and engineered barriers that together will isolate high-level radioactive waste from the biosphere for thousands of years. The most cost-effective way to increase public confidence in the long-term combined performance of the multibarrier system for waste isolation may be to ensure that an engineered barrier system by itself meets the minimum legal requirements for containment time.

Even under the best of circumstances, however, technical uncertainties will persist about the performance of any geologic repository. For example, what will the site's climate be in 10,000 years, and how could climatic changes affect repository performance. The lower the level of uncertainty, the greater the confidence the technical community and the public will have in geologic disposal of high-level radioactive waste. Unfortunately, data for assessing some crucial issues are and will remain scarce or unavailable. A need may exist to use modeling techniques combined with the collective judgment of technical experts to assess long-term repository performance. In fact, the validity of models and the credibility of expert judgment are likely to become important and potentially controversial issues in the licensing and public acceptance of a repository.

As with similar facilities, such as dams and nuclear power plants, licensing standards will be applied to the development of a repository; however, since no country in the world has yet developed and operated a permanent geologic repository for high-level radioactive waste, there is little practical experience upon which to base such standards. Regulatory standards must be developed prior to disposal to ensure public safety and environmental protection. They should not be so restrictive, however, that they would foreclose at the outset any and all candidate sites that can subsequently be shown to be suitable based on sound scientific and engineering considerations.

The nation is undertaking three tasks simultaneously. The first consists of the DOE's efforts to characterize the site and determine its suitability. At the same time, the EPA and NRC are developing standards and regulations that will affect site-characterization activities and the design, construction, and

operation of a waste repository, including the logistics of safely delivering wastes to the repository. A third concurrent challenge involves establishing confidence that the federal agencies and their contractors will be candid and forthcoming with an often skeptical public.

The Board expressed concern in its *First Report* about the delay in exploratory activities at the Yucca Mountain Site in Nevada. Yucca Mountain has not been chosen for a repository. Rather, it is the only candidate site in the United States currently being characterized to determine its suitability. Site- characterization activities have been delayed during the past months because the DOE and the State of Nevada are in litigation over the status of the site. A September 1990 decision by the Ninth U.S. Circuit Court favored the DOE; however, Nevada may appeal. If the state appeals, the DOE's site-characterization activities at Yucca Mountain undoubtedly will be delayed further.

In its *First Report*, the Board made a number of recommendations and grouped them into three categories: (1) technical and scientific, (2) strategic technical and nontechnical, and (3) scientific policy. (See Figure 1-1 for a breakdown.) The DOE has responded to many of these recommendations; a detailed DOE report on its responses is included in Appendix E. In this second report, the Board's recommendations are organized within the framework of individual panel activities.

B. Board and Panel Activities January 1 to July 31, 1990

As in its first year, the Board conducted its evaluation of the DOE's high-level waste disposal program through discussions; briefings to the full Board and its panels by representatives of the DOE and others; reviews of the DOE's Site Characterization Plan (DOE 1988) and other DOE studies; reviews of selected literature by individual members and staff; and through participation in field trips. The panels also reviewed DOE work already performed or underway. Individual panel reports, which are available to the public from the Board's Washington office, describe the extent and specific nature of each panel's review activities.

At the March 3, 1990, meeting in Tucson, Arizona, the Board divided the Containers and Transportation Panel into two panels: the Engineered Barrier System Panel and the Transportation Panel. The latter panel's name was changed again at a later meeting to Transportation & Systems Panel. This change reflects the broad scope of the panel's work.

Recognizing that quality assurance is an important regulatory requirement and management function designed to ensure the soundness and integrity of the scientific and technical undertakings in the waste management program, the Board established the Quality Assurance Panel, which will present results from its future deliberations in subsequent reports.

The Board now comprises seven panels: Structural Geology & Geoengineering, Hydrogeology & Geochemistry, Engineered Barrier System, Transportation & Systems, Environment & Public Health, Risk & Performance Analysis, and Quality Assurance. Of these, five panels have made sufficient progress within this reporting period to make recommendations for inclusion in this report.

In addition to panel and individual member activities, the Board, as a body, visited Sweden and the Federal Republic of Germany for a week this spring to discuss and observe, firsthand, their national nuclear waste management plans, philosophies, technologies, and practices. The Board will report on this trip in a separate document.

On April 19, 1990, the terms of Board members Drs. D. Warner North, Dennis L. Price, and Ellis D. Verink expired. President Bush reappointed Drs. North and Price to serve for four additional years, until April 19, 1994. Dr. Verink's reappointment is still pending. On May 31, President Bush appointed Dr. Patrick A. Domenico, a hydrogeologist, to a four-year term on the Board.

The conclusions and recommendations presented in this report reflect the many panel meetings, field trips, and technical reviews conducted during this reporting period. However, they also reflect the Board's technical judgment grounded in the collective experience of its members.

Figure 1-1

Board Recommendations Presented in the *First Report*

The Board made recommenations in its *First Report* in the following categories.

Technical and Scientific Recommendations

A. Mechanical excavation
B. Ghost Dance Fault
C. Early exploratory drifting
D. Exploratory ramp
E. Nonwelded tuff
F. Excavation-testing sequence
G. Unsaturated zone recharge
H. Fracture flow
I. Hydrogeologic modeling
J. Calico Hills hydrogeologic properties
K. Adsorption in unsaturated tuffs
L. Radionuclide adsorption workshop
M. Performance assessment methodology
N. Preliminary performance assessment
O. RADTRAN/TRANSNET
P. Risk models user-needs assessment
Q. ^{14}C Release mechanism

Strategic Technical and Nontechnical Recommendations

A. System safety
B. Human factors
C. Operational planning
D. Environmental and public health program

Scientific Policy Recommendations

A. DOE/State of Nevada interactions
B. The EPA Standard 40 CFR 191
C. Uncertainties in setting standards

*This is not a ranking. Topics are listed according to their appearance in Sections 1 through 5 of the *First Report*.

Chapter 2
Areas of Inquiry and Recommendations

The topics addressed and recommendations made in this second report to Congress and the Secretary of Energy have evolved as a result of activities undertaken by the Board and its panels. All but the Quality Assurance and Hydrogeology & Geochemistry panels submitted reports to the Board during the reporting period, January 1-July 31, 1990. A chronological list of the Board's activities (beginning January 1, 1990, and including those scheduled for the future) is included in Appendix C. A list of formal presenters at Board and panel meetings can be found in Appendix D.

Briefly, the major areas of activity can be broken down in the following way:

Structural geology refers to the study of the deformational features of rocks induced by processes such as folding, faulting, and igneous activity. As used in this report, it also includes a study of the processes themselves. *Geoengineering* refers to the design, construction, and performance of the exploratory shaft facilities, surface drilling operations, and underground openings at the repository, taking into account the engineering properties of the geologic materials and their spatial variations.

Hydrogeology refers to the study of the geologic aspects of surface and subsurface waters. At the Yucca Mountain Site, emphasis is placed on the study of fluid transport through the rock matrix and fractures. Groundwater is the primary means by which radionuclides (atoms that are radioactive) could be transported from the repository to the accessible environment. *Geochemistry* at the Yucca Mountain Site is concerned primarily with the potential migration of radionuclides to the accessible environment. Geochemists are studying the chemical and physical properties of the minerals, rocks, and waters that might affect the migration of radionuclides from a repository.

The engineered barrier system refers to the waste package, borehole, and repository openings. It includes methods of construction, the near-field host rock, and the backfilling and sealing of all openings. It may be possible to improve confidence in the reliability of the repository to isolate waste from the accessible environment by relying on geologic barriers *in combination with* a more robust engineered barrier system.

Transportation and systems refers to a system for moving spent nuclear fuel from the more than 100 commercial nuclear reactors located at 70 sites throughout the nation and the high-level radioactive waste from DOE defense facilities to a disposal site. It is not merely the activities associated with packaging spent fuel in a shipping cask and shipping it by highway, rail, or water. Transportation and systems also includes all processes involved before and after the trip—removing spent fuel from its storage facility, loading it into the cask, loading and unloading it at the various handling sites, storing it, and finally emplacing it in the repository.

Environmental issues cover the effects that site-characterization activities and development, operation, and decommissioning of a repository could have on the biosphere, which includes air, water, soil, biologic, cultural, and socioeconomic resources at and downstream, in surface water or groundwater, or downwind from the site for thousands of years. *Public health* issues involve potential direct or indi-

rect effects on human health both during repository development and operation and after its closure. The possible public health and environmental consequences of the handling and transportation of high-level radioactive waste from points of origin to the repository are also of concern.

Risk and performance analysis refers to the analysis of the long-term performance of a waste repository. Such analysis provides a means for incorporating all scientific and technical aspects into an integrated description of the entire repository system. Performance analysis also can be used to determine which site-characterization studies need to be emphasized or moderated to provide better information on site suitability.

Chapter 2 is organized into sections according to the foregoing topics. Where the Board's investigation and research have progressed sufficiently since the previous report, recommendations are included. Some of the issues raised here, however, have not yet been examined thoroughly enough by the Board to warrant recommendations at this time. The Board intends to explore such issues further.

Recommendations made in this chapter, while addressing activities of a variety of state and federal agencies, are intended to aid the DOE in its efforts to improve technical work being conducted at Yucca Mountain Site, to assist the DOE in its overall plan to study the site and identify as soon as possible any disqualifying site characteristics, and to identify areas for possible improvement in the DOE's transportation program. The Board also identifies areas of future inquiry that may eventually affect our current legislative and regulatory framework.

Section 1: Structural Geology and Geoengineering

The early evaluation of the suitability of the Yucca Mountain geologic block for a potential repository continues to be of prime concern to the Board. With the refocusing of early scientific studies by the DOE toward issues of site suitability, structural geology and geoengineering continue play a major role in the Board's activities. In particular, issues relating to (1) tectonic features and processes and (2) geoengineering—specifically, the design of the repository and the early evaluation of the suitability of the geologic block—are addressed in the following sections.

Tectonic Features and Processes

In its *First Report*, the Board identified three broad areas relating to tectonic features and processes that require extensive inquiry: (1) volcanism, (2) seismicity and faulting, and (3) geologic licensing standards and criteria. Since that report was issued in March 1990, the Board has focused its attention primarily on seismicity and faulting. Efforts by the DOE with respect to volcanism are proceeding with the emphasis on data gathering (e.g., radiometric age dating). When these data and their interpretations become available, the Board will meet and further discuss this important issue with the DOE.

As a result of its many activities, the Board suggests that some of the geologic issues associated with determining site suitability need to be placed in a broader context by the DOE than appears to be the case at present. Each issue should be examined and, if necessary, reformulated with respect to the specific problem being addressed, in particular its implications for public safety and environmental protection. The following discussion describes the Board's views on these issues and the context within which they need to be treated.

A. Seismicity and Faulting

In its *First Report*, the Board raised general concerns about the possible effects of earthquake-related ground motion and fault displacement on the surface facilities that would be operative during the operating and preclosure phase and on the waste canisters and groundwater depth and flow patterns, which are of prime importance during the postclosure phase. On the basis of available reports and observations made during field trips, it appears that geologically recent faulting (i.e., within about the past million years) in the Yucca Mountain region is relatively widespread, as is true for many other parts of the Western United States. This faulting presumably was associated with prehistoric earthquakes.

Late Quaternary displacements (i.e., within about the past million years) on several faults near the site have already been relatively well documented, and it is likely that some of these faults have, in addition, experienced Holocene displacements (i.e., within about the past 11,000 years). Displacements during individual prehistoric earthquakes tentatively appear not to have exceeded a few tens of centimeters on individual faults, although the possibility that several faults might have ruptured simultaneously during a single, relatively large regional earthquake cannot as yet be ruled out. Furthermore, it seems likely that field stratigraphic evidence along some faults may turn out to be inadequate to prove whether or not late Quaternary displacements have occurred there. In these cases, prudence may make it necessary to assume that they have the same degrees of activity as nearby faults for which late Quaternary or Holocene displacements can be documented. In particular, the Ghost Dance Fault, which cuts through the repository block itself, may turn out to be in this category. If so, there could be ramifications for understanding postclosure groundwater flow within the repository block.

It is the Board's opinion that these relationships in themselves by no means imply that the site is necessarily unsuitable. Suitability should be judged on the basis of the potential *risk* (the likelihood of such adverse consequences as the release of radionuclides to the accessible environment), not on just the potential occurrence of natural phenomena alone, such as earthquake ground motion or fault displacement, in-

dependent of their consequences. The consequences of loss of function or failure, and the ability of good engineering and planning to prevent this loss or failure, must be taken into account. Otherwise, many large regions in the United States and throughout the world would unnecessarily be considered unfit for construction or human habitation simply because they have experienced earthquakes. For example, many very large dams, whose consequences of failure could be catastrophic, have been built safely around the world in highly seismic areas—far more active than that of the Yucca Mountain region—by using appropriate engineering planning and design and by exercising adequate conservatism to compensate for uncertainties.

In this light, the Board suggests that it would be wise at this early stage in the site investigations to assume tentatively that relatively large local seismic events may occur during both the pre- and postclosure periods of the repository life and to investigate the engineering and safety consequences of such events. It is the opinion of the Board that the vibratory ground motion associated with a relatively large local earthquake, and even some surface faulting beneath critical areas of the loading facility—however unlikely—may not entail untoward concerns for public safety, provided that they are adequately foreseen and compensated for in the engineering design. Nor should the possibility of postclosure faulting through the repository area itself necessarily be a disqualifying condition, provided that its engineering and hydrologic implications have been adequately addressed prior to waste emplacement.

Consequence analyses are integral parts of performance assessment. However, useful insights need not await the completion of a full performance assessment. Initial efforts have been made by the DOE to evaluate the significance of earthquakes for the repository complex, but apparently these studies have not received the level of attention they deserve. Such risk-oriented studies also would help focus the extensive geologic and hydrologic studies on those properties that can have a real impact on public safety and environmental protection.

Although much work remains to be done to understand better the history of individual fault displacements and the potential for future displacements and associated earthquakes, the Board believes that some residual uncertainties inevitably will remain in gaining a complete understanding of local faulting in the Yucca Mountain area. Likewise, despite the great emphasis by the DOE and the NRC on the development of a rational "tectonic model" for the region, the Board is skeptical that available geologic and geophysical techniques will permit formulation of a specific tectonic model on which everyone will agree. Nor is such a model necessarily needed, in the Board's opinion, to have confidence that public safety and environmental protection can be adequately assured.

This is not a situation that is by any means unique to the Yucca Mountain region. Similar geologic and seismologic uncertainties have characterized almost every critical facility (nuclear power plants, large dams, etc.) worldwide. Such uncertainties have usually led to the assumption of conservative design-basis earthquakes (i.e., earthquake occurrences for which given facilities must be designed). Taken in conjunction with conservative engineering criteria and practice, this most often enables the constructed facility to safely withstand even exceedingly unlikely events and avoid or minimize adverse consequences. It is in this light that the Board recommends that increased attention be given to understanding the engineering, safety, and environmental consequences of seismic events at Yucca Mountain, including earthquakes of magnitudes larger than those that are likely to occur during the lifetime of the facility. In this process, it is important to remember that a nuclear waste repository is very different from other types of critical facilities in the length of its service life and in the types and consequences of the various kinds of accidents or unlikely natural events that may affect it.

The Board notes that the National Academy of Sciences/National Research Council (NAS) has formed a panel to evaluate coupled processes (hydrologic, tectonic, and hydrothermal) at Yucca Mountain. The conclusions of the NAS panel will undoubtedly assist all those involved in estimating the effects of earthquakes and tectonic strain on groundwater depth and flow regime.

B. Regulatory Framework for Repository Siting and Licensing*

In its *First Report*, the Board expressed concerns that, while the EPA standards and the NRC licensing regulations and guidelines for the repository must be adequately conservative, they should not impose restrictions that would foreclose at the outset a site that might subsequently prove to be suitable based on sound scientific and engineering considerations. For example, this could come about through the application of specific criteria that have little or no impact on public safety and environmental protection, or criteria that effectively impose a much more stringent standard than that envisioned by overall performance goals.

Over the past few years, there has been considerable discussion about the applicability of Appendix A to 10 CFR Part 100 ("Seismic and Geologic Siting Criteria for Nuclear Power Plants") to the waste repository. The advantages of using these criteria lie in the fact that they are a known quantity, having been used and litigated in the licensing of many nuclear power plants for almost 20 years. The disadvantages are that these criteria are based on the state of knowledge and technology current during the late 1960s and early 1970s and that they were written for nuclear reactors, not repositories. During the past 20 years, our understanding of the earth, including earthquakes, has increased dramatically. In addition, nuclear reactors are highly complex, relatively short-lived surface facilities requiring sophisticated control technologies, where an accident could possibly result in the immediate release of a large amount of radionuclides. This description has only limited applicability to the preclosure surface facilities of a repository and is not applicable to the underground repository itself.

It is the Board's view that Appendix A to 10 CFR Part 100 should not be used to site and license the repository and its surface facilities. The Board is encouraged by the fact that both the NRC and the DOE are moving away from its use at Yucca Mountain. These and other criteria and standards should be judged on the basis of (1) the problem that is being addressed, (2) the scientific and engineering state-of-the-art and accepted practice at the time of application, (3) the adverse consequences being considered, (4) our technical ability to mitigate these adverse consequences, and (5) legal and regulatory concerns.

C. Recommendations (Tectonic Features and Processes)

On the basis of the foregoing discussion, the Board makes the following recommendations.

1. Increased emphasis should be placed on understanding the engineering, public safety, and environmental consequences of seismic events at Yucca Mountain, including earthquakes of magnitudes larger than those that are likely to occur during the lifetime of the facility.

2. Discussions of site suitability should be based on the likelihood of adverse consequences and not on the occurrence of earthquake ground motion or fault displacement alone.

3. Formulation of a specific tectonic model, acceptable with a high degree of confidence, should not be viewed as a prerequisite to site suitability or to ensuring public safety and environmental protection.

4. Geologic licensing criteria and standards for the repository and its surface facilities should reflect the nature and relative vulnerability of the repository complex and the problems it poses. The criteria and standards should ensure public safety and environmental protection in the light of current scientific knowledge and engineering practice, including the feasible mitigation of adverse consequences.

* The regulatory framework for repository licensing consists of EPA standards, NRC regulations specified in the Code of Federal Regulations (CFR), and nonbinding NRC guidelines.

Geoengineering

A major Board activity has involved reviewing the geoengineering aspects of the Yucca Mountain geologic block evaluation. To better understand the design and technical needs of the exploratory facility, the Board has reviewed the DOE design of the proposed repository, which places emphasis on thermal loading. The following sections review the proposed repository design, the status of the DOE studies evaluating the geologic block, issues of concern, and recommendations.

A. Repository Design

The design of the proposed repository at Yucca Mountain includes more than 100 miles of drifts (tunnels) approximately 1,100 feet below the surface of the mountain and spread over approximately 2 square miles. Congress limited the amount of high-level nuclear waste that could be placed in the repository to 70,000 metric tons, which will consist of 62,000 metric tons of spent fuel in approximately 25,000 waste packages and 8,000 metric tons of defense high-level waste in approximately 15,000 waste packages.

The repository horizon is to lie within the Topopah Spring welded tuff, which is bounded above by the Paintbrush nonwelded tuff and below by the Calico Hills nonwelded tuff. (See Figures 2-1 and 2-2 for a cross-sectional view of the proposed repository location and an artist's rendering of the proposed repository.) The distance below the repository to the regional water table ranges from 1,320 feet on the southwest side to 550 feet on the northeast side.

The Topopah Spring welded tuff will be used as the host rock because extensive, structurally sound underground openings can be readily excavated in it. The nonwelded tuff above is less fractured and thus assumed to provide fewer fracture pathways for the flow of groundwater into the repository horizon; presumably, the nonwelded tuff below would likewise retard the flow of groundwater through fractures from the repository horizon to the regional water table. An important characteristic of the Calico Hills nonwelded tuff is that it contains significant quantities of zeolite minerals, which have strong sorption characteristics for some radionuclides, thereby augmenting the combination of barriers to the possible migration of radionuclides from the repository to the regional water table.

Spent fuel assemblies release heat as the fission products in the fuel rods decay. The thermal output (i.e., energy release) of older fuel assemblies, for example, is reduced, resulting in reduced transmission of energy to the host rock after emplacement. The thermal loading of the repository would be controlled by mixing the ages of the spent fuel loaded into each waste package and by appropriately spacing the waste packages in the repository.

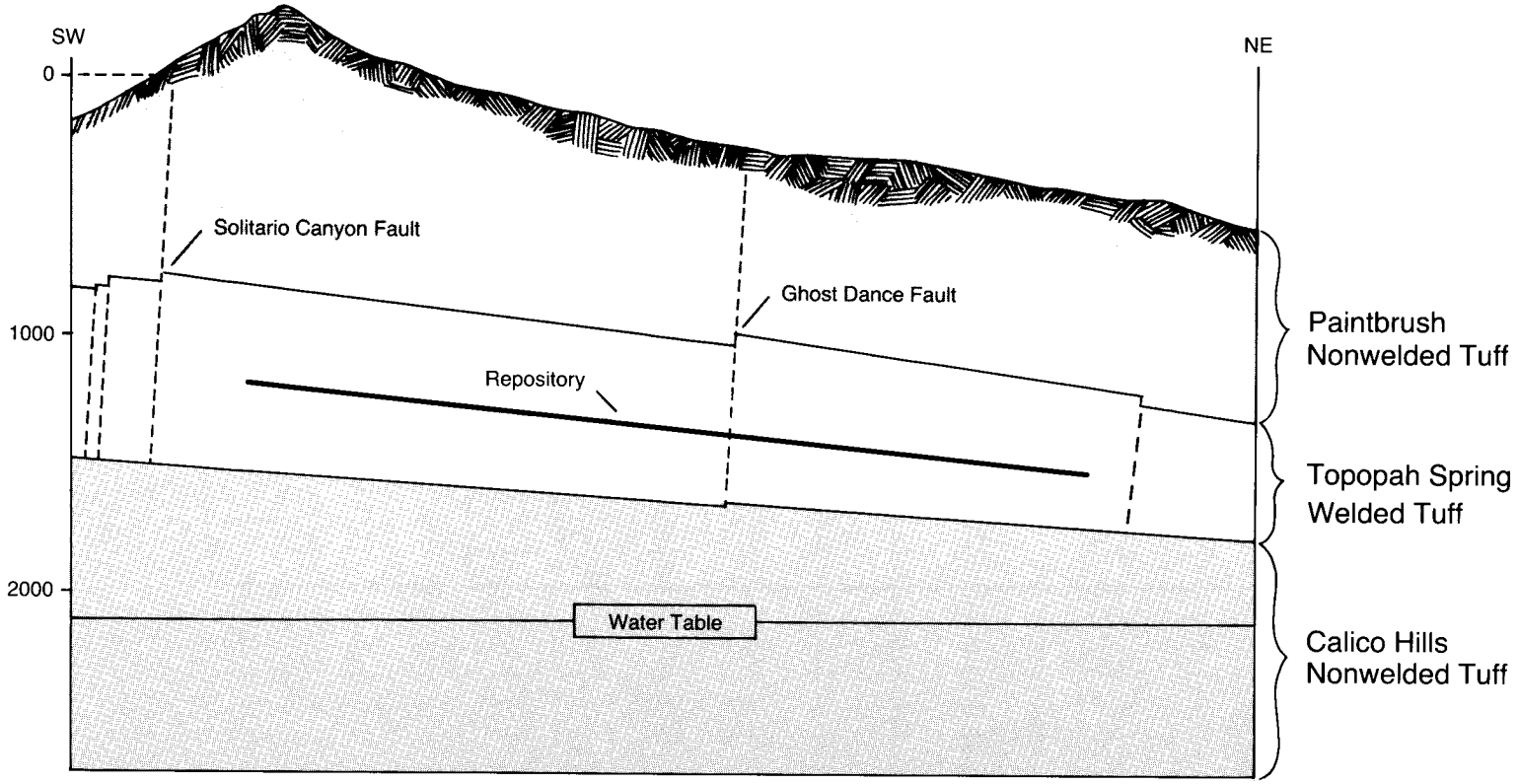
The proposed design of the repository and waste package calls for maintaining the near-field temperature of the waste package above the boiling point of water for 300 years or longer to drive any groundwater away from the waste packages, thus minimizing the potential for corrosion. At the same time, temperatures would be kept low enough to avoid potential degradation of the waste package and the geologic barriers.

B. Geologic Block Evaluation

In its *First Report*, the Board made a number of suggestions for improving the DOE's Site Characterization Plan for evaluating the Yucca Mountain geologic block. The Board suggested that the DOE (1) mechanically excavate shafts and drifts to reduce disturbance to the rock walls that results from drilling and blasting; (2) explore the Ghost Dance Fault via drifts in more than one location; (3) add an early east-west exploratory drift across the geologic block to reduce uncertainties and to increase confidence that potentially disqualifying geologic features are found as early as possible; (4) consider an inclined ramp into the geologic block as an alternative to one of the proposed exploratory shafts; (5) map fractures of shaft and drift walls that are undisturbed by blasting; (6) explore the nonwelded tuff units above and below the repository level both by surface-based borings and by shafts and drifts; and (7) develop innovative ways of coordinating and sequencing excavation and scientific testing.

Figure 2-1

Cross Section Showing Proposed Location of the Repository in the Host Rock at Yucca Mountain (Artist's Rendering)

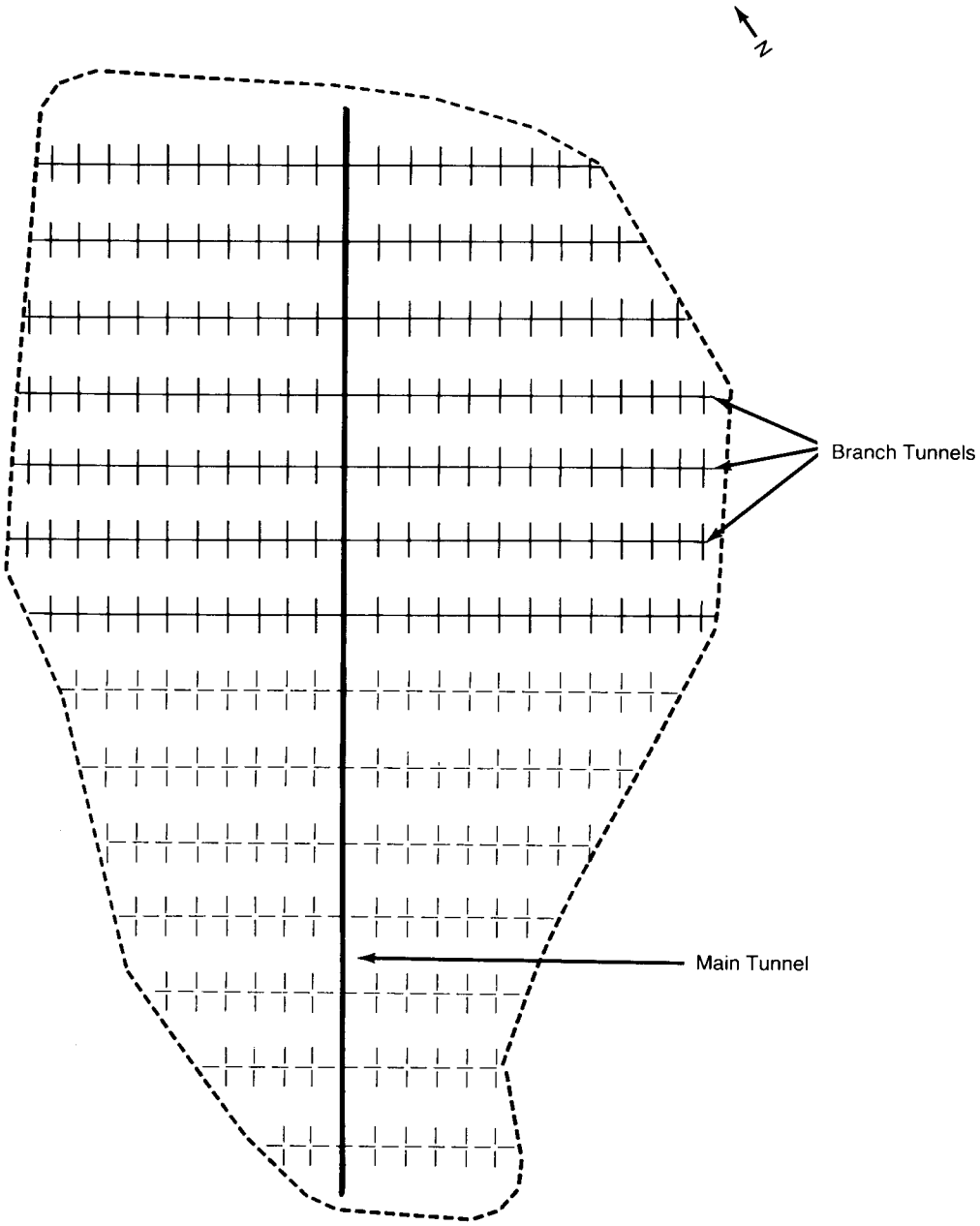


The proposed repository would be located in the Topopah Spring welded tuff (host rock). The host rock is bounded by the Paintbrush nonwelded tuff above, and the Calico Hills nonwelded tuff below.

Source: Adaptation of U.S. Department of Energy drawing.

Figure 2-2

Plan view of the Proposed Repository Configuration (Artist's Rendering)



The proposed repository would consist of more than 100 miles of tunnels covering about 2.2 square miles, approximately 1,100 feet below the surface. Access to the repository would be through a long, inclined tunnel from the surface. Number and location of tunnels will probably change as repository designs are revised.

Source: U.S. Department of Energy drawings.

The DOE has responded positively to the Board's concerns. The Secretary of Energy in his November 1989 *Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program* (DOE 1989, *Report to Congress*), said the DOE's scientific investigations need to be refocused on determining early site suitability. Subsequent studies defined by the DOE to refocus and reassess its site-characterization program accommodated suggestions made by the Board and others.

Early in 1990, the DOE initiated a task force study that would systematically evaluate and select a preferred alternative for developing the exploratory shaft facility (ESF). Following this, the DOE initiated two additional task force studies to prioritize surface-based testing and to perform a Calico Hills risk/benefit analysis. The prioritization study of surface-based testing is defined to help the DOE direct near-term testing to the early detection of any unsuitable conditions. The Calico Hills risk/benefit analysis study compares the benefits of excavating shaft(s) or horizontal drifts into the Calico Hills unit and assesses how excavation and testing might adversely affect repository performance.

The DOE has applied decision-analysis techniques to add rigor to analyzing the many alternatives involved; to define a process that may be reiterated if new alternatives, data, or technology are identified; and to document the analytical basis for the final recommendations.

Several Board concerns regarding the various DOE task force studies are described in the following section.

C. Concerns

Repository design

The Board feels it is essential to understand the relative merits of alternative repository configurations and designs especially the factors influencing the thermal loading on the repository host rock and the Calico Hills nonwelded tuff. Uncertainties persist concerning mineral and permeability alterations, including potential changes in the mineral sorption characteristics of the zeolites that could result from the anticipated thermal loading. A better understanding of the heat-pipe effects that occur when groundwater vaporizes and condenses near the waste packages also is needed.

Decision-analysis techniques

The Board concurs that using modern decision-analysis techniques can help the DOE study very complex issues. However, using decision-analysis techniques does not reduce the need for good technical judgment by DOE managers. On the contrary, prudent technical judgment should be used in defining reasonable and rational sets of alternatives to be evaluated by these or other decision-aiding techniques. The Board encourages the DOE to evaluate thoroughly the "robustness" of the analyses by determining the sensitivity of given analyses to various alternatives, to various quantitative data, and to variations in investigators on expert panels (e.g., in-house vs. external investigators).

Testing needs and priorities

The Board feels that the tests identified in the Site Characterization Plan and tentatively associated with assessing early site-suitability should be reviewed (in terms of procedure, technology, test location, and appropriateness in meeting stated objectives), and a recommended *testing priority* should be established. This is particularly true for testing in the unsaturated zones, so that early assessments can be made regarding the adequacy of state-of-the-art site-characterization technologies. Some of the testing data can be obtained in several ways. Lower priority tests could be set up to take advantage of available space and time. Testing should not dictate the construction of the facility.

Site suitability

The Board feels that a major site-suitability issue involves the potential flow of groundwater through the nonwelded tuffs above and below the repository horizon. Much of this flow will be controlled by near-vertical geologic features, particularly faults and continuous joints. The Board believes that horizontal access to the upper and lower nonwelded tuff units, as well as to the repository horizon, must be made early, with the purpose of viewing and testing these near-vertical features, which cannot be adequately characterized solely by vertical drilling from the surface.

Horizontal exploration

The Board is pleased with the scope and direction of the Calico Hills risk/benefit analysis study and concurs that detailed testing at one location is of little value if the range of conditions and variations within the geologic block is not understood. The Calico Hills study should be integrated with the analysis of ESF alternatives. Assumptions regarding frequency and tightness of joints and faults in the Calico Hills study must be correlated with the extent of drifting proposed in the ESF alternatives analysis study.

Inclined dry-drilling

The Board is impressed with the DOE's development of prototype equipment to drill and recover core from vertical boreholes in rock several thousand feet deep without introducing water into the drilled formations. However, the capability to recover core with *inclined* dry-drilling would allow the investigation of the high-angle joint and fault systems as part of the surface-based testing. In this way, surface-based drilling can be better integrated with subsurface drifting requirements.

D. Recommendations (Geoengineering)

The Board wishes to make the following recommendations to the DOE.

1. Planned scientific testing of the Yucca Mountain geologic block should be re-evaluated to give highest priority to those tests and studies that provide the data essential to assess the suitability of the site. Each proposed study should be evaluated in terms of procedures, technologies, test locations, and appropriateness in meeting stated objectives.

2. The DOE should consider expanding its development program for dry-drilling equipment to include the capability to drill inclined holes.

Section 2: Engineered Barrier System

During the Board's first year of work, it identified several engineering design and/or policy decisions made by the DOE over the years that could affect the ability of the proposed repository at the Yucca Mountain Site to contain high-level radioactive waste. As a result, the Board decided to investigate the relative roles of the geologic barrier and the engineered barrier system in providing containment and controlled release of nuclear wastes. This area of inquiry is critical to predicting probable performance of the repository.

In addition, the Board believes that well-engineered structures are less variable and more predictable than rock formations. Therefore, it should be possible to reduce overall uncertainty concerning the repository's long-term performance by relying on geologic barriers *in combination with* a more robust engineered barrier system designed to retain the waste materials for thousands of years.

One of the Board's goals in the past seven months has been to address the aforementioned issues and to obtain a broader understanding of the repository's design and the DOE's current program to develop an engineered barrier system. To achieve this goal, the Board's panels were reorganized. The Engineered Barrier System (EBS) Panel was created to handle activities related to the engineered barrier system that had been covered previously by the Containers and Transportation Panel.

In January 1990, the EBS Panel asked the DOE four questions intended to describe the Board's interests in the area of EBS development and design and to help the DOE focus its presentations and future activities. These questions were

1. Can a waste package be developed that can be demonstrated to have reasonable assurance of lasting 10,000 years? If yes, how? If no, why not?

2. What ambient conditions or factors need to be modified for a 10,000-year waste package to be attained if this, indeed, is not yet possible?

3. How would the probability of attaining a 10,000-year waste package be influenced if the as-emplaced heat generation rate of individual canisters were minimized? A detailed explanation of any conclusions should be developed.

4. How does the siting of the repository in an unsaturated zone, as opposed to a saturated zone, affect attaining a 10,000-year waste package? Consider alternative construction materials and/or costs. A detailed exposition of the conclusions is needed.

A. EBS Development Program

To date, the Board has primarily examined the activities associated with the design and development of the waste package container. In addition to attending technical presentations, Board members have toured laboratories where potential container materials are being studied. As a result, the Board has been able to evaluate current DOE studies in two areas: the waste package environment and the selection of materials for waste package containers. Studies of the waste package environment have included hydrologic, geochemical, thermal stress, and radiation interactions. A small horizontal rod-heater test in welded tuff has been performed by a DOE contractor. This study included measurements of temperature, water content, and thermal stresses immediately surrounding the heater. The purpose of the heater test was, in part, to confirm the results of biaxial calculations. These experiments demonstrated that the general thrust of calculations is informative; however, more detailed site-specific conditions should be considered.

The results of several modeling studies of near-field conditions have been evaluated. The modeling studies of fractures consider the width of the fractures and their spacing. However, there seems to be no attempt to relate these near-field studies to other repository characteristics such as the contribution of fractures to the permeability of the host rock.

Little direct experimental work has been accomplished recently by DOE's primary contractor, Lawrence Livermore National Laboratory (LLNL). Much of the experimental data seen, both at meetings with the DOE and during the laboratory tours, have been developed at DOE laboratories other than LLNL. The DOE and LLNL acknowledge that the principal effort expended during the past year has centered on the development and implementation of a quality assurance (QA) program.

Although radiation-induced corrosion processes could have an important effect on some container materials, studies of these potentially important effects have been given lower priority than other phases of the DOE's EBS program. Studies of possible mechanisms for controlling the immediate environment around the container are not under consideration. Such studies might provide additional assurance of extended life for the containers in the event of drastic environmental changes, such as might occur under saturated or near-saturated conditions. There is no apparent overall strategy that integrates ongoing container studies with those related to host-rock and waste-form interactions. Furthermore, high-emplacement temperatures proposed by the DOE seem to rule out the use of additional engineered barriers, such as grouting, bentonite, or other backfill materials, to surround waste canisters.

The Board believes that the potential contribution of additional engineered barriers to overall repository performance should be ascertained.

B. Conclusions

Because the Board's inquiries are in their early stages, it is not possible to assemble a complete set of conclusions on the entire EBS program. However, some conclusions can be reached about DOE's container material and near-field environment studies.

Work to date

Apparently, work by the DOE to date primarily has involved literature reviews and QA activities. Little actual experimental work has been performed, although personnel and facilities are judged capable of such work.

Alternative container materials

While recognizing the finite limitations on the cost of an engineered barrier system, there is concern about the DOE's apparent tendency to eliminate prematurely promising alternative container materials and engineered barrier system studies because of perceived high initial cost.

Alternative emplacement and container configurations

Currently, no studies aimed at developing alternative emplacement procedures or container configurations are ongoing. Inasmuch as present schedules provide approximately seven years for EBS development, now would seem an opportune time to identify and evaluate practical alternatives to the current baseline (or reference) systems.

Control of environment

No effort is directed at developing mechanisms for controlling or coping with the environment immediately adjacent to the waste containers in anticipation of drastic changes in local conditions (e.g., a change from unsaturated to locally saturated conditions).

Radiation-induced corrosion processes

Insufficient priority has been given to the study of the influence of radiation-induced corrosion processes that could affect both the interior and exterior of the containers.

Heater tests

Heater tests in welded tuff have been shut down without testing a vertical configuration or an array of several heaters. It is hoped that this important field experimentation can be reinitiated. Meanwhile, laboratory studies (or comparable in-situ field studies) should continue.

Integration of present activities

At present, it is not clear how the diverse array of on-going activities are to be integrated into the overall repository development effort.

C. Recommendations

The Board recommends the following actions to the DOE.

1. At a future meeting, the DOE should respond to the EBS Panel's four questions of January 6, 1990, relating to EBS performance. It should be emphasized that the Board's interest in a robust, extended-life EBS does not imply a diminished interest in the geologic barrier's contribution to overall repository performance; rather, the Board is suggesting engineered barriers may reduce the adverse consequences associated with difficult-to-predict geologic or climatological events.

2. Studies of alternative materials should be restarted. These studies should include evaluation of container materials and designs, emplacement designs, and container configurations, including both internal adsorbing materials and external back-fill materials.

3. Heater tests should be reinitiated. These tests should examine the effects of alternative emplacement orientations and three-dimensional and multiple heat sources for a range of thermal loads.

4. The EBS development and testing program should be coordinated and funded at a level sufficient to produce a statistical basis for assessing its contribution to long-term predictions of repository behavior. Tests should be long-term—preferably exceeding five years—and include both laboratory and field testing.

5. A workshop should be held to investigate the practicality, advantages, and disadvantages of developing a robust, extended-life EBS that would contribute to containment for periods of time well beyond 1,000 years. The Board would be pleased to assist in developing an agenda for such a workshop.*

* (See Chapter 3 for a discussion of a recent Nuclear Regulatory Commission clarification on waste package performance criteria.)

Section 3: Transportation and Systems

The Board views spent fuel transportation in a systems context. Transportation encompasses more than the activities associated with packaging spent fuel in a shipping cask and shipping it by highway, rail, or water. System concerns also include all processes involved before and after the trip, including removing fuel from the storage facility, loading it into the cask, loading and unloading it at points of origin and destination, storing it, and finally emplacing it. The Board's recommendations largely reflect this system view.

In its *First Report to the U.S. Congress and the U.S. Secretary of Energy*, the Board identified an initial set of transportation issues and made recommendations to the Department of Energy. This initial set of issues was selected, in part, because of the opportunity to affect transportation system planning while it is still in its early stages. Two of the recommendations were that the DOE include (1) system safety and (2) human factors engineering programs as part of the Office of Civilian Radioactive Waste Management effort. These programs not only ensure the safety of transport operations but also include emergency preparedness plans in the event of accidents. The Board continues to believe in the appropriateness of these recommendations, and, during this reporting period, worked to expand on them. This work included meeting with representatives of the NRC on these topics and on minimizing handling of spent fuel.

A. Safety Management Techniques: System Safety and Human Factors

Spent fuel has been shipped routinely for the past 40 years, and safety performance has been very good. The Board recognizes that the technologies for providing safe transport have been and are available.

The Board also recognizes, however, that once the planned waste disposal shipments to a repository are underway, the number of annual shipments of spent fuel and high-level radioactive waste will increase dramatically from historical levels. The number of persons involved in and who may be affected by such shipments also will increase, as will the level of public awareness and concern. New equipment and systems also will be developed and implemented at reactor sites, at the repository site, and perhaps at sites in between. These personnel, equipment, and system changes will need to be evaluated for new hazards. Hazards that have not been apparent because they did not cause incidents or accidents during the relatively infrequent shipments in the past may become apparent when the scale and diversity of operations are significantly increased. Therefore, the need exists to implement techniques that will do more than just maintain the current level of safety activity. The Board believes that system safety and human factors engineering programs are among those management tools that will help fulfill that need.

Furthermore, significant changes in the transportation system will occur. Changes that affect loading operations are taking place at reactor sites, and handling efficiency is improving. Interim storage facilities and monitored retrievable storage facilities between reactor sites and the repository may be developed. The repository handling and receiving facilities, and the transfer-to-emplacement facilities are yet to be designed. The amount of spent fuel being transported will be increased considerably. New procedures will be necessary, and new cask designs put in service. These changes will bring about new exposure and accident potentials. The opportunity exists now for all parties involved in the high-level nuclear waste management system to address these changes and their effects *before, rather than after*, they occur. These parties include the DOE, the utilities, the Nuclear Regulatory Commission, the Department of Transportation, and the states.

Technology exists today that could contribute to anticipating and reducing the number and severity of accidents and could optimize system operations. The DOE may adopt programs in system safety and human factors engineering of its own volition; however, it is not the only participant in the waste management process. The utilities individually may

institute varying levels of system safety or human factors procedures.

The NRC has a useful role to play in facilitating and harmonizing the process. The NRC could provide statements of policy and program guidelines on human factors, safety engineering, and systems integration that would be applicable for all systems acquisition programs for which the commission is responsible. Such guidelines would be helpful to the DOE's program for civilian waste management and to its contractors in maintaining or improving an already high safety level and in building public confidence in the system's safety.

The waste management and disposal system will be large and complicated, even if various components and pieces of equipment are designed and acquired in a systematic fashion. Overall safety can be enhanced, however, if these interactions and potential system hazards are considered in a disciplined way.

Systems acquisition programs in other governmental agencies routinely provide policy statements, guidelines, and criteria documents in human factors and systems safety. Examples include the Department of Defense human factors program document, MIL H 46855; the system safety program document, MIL STD 882 B; and the human factors design criteria document, MIL STD 1472.

These documents, usually part of acquisition contracts, ensure that hazards are identified, unnecessary risks are avoided, and the system being acquired is operable. The NRC should consider developing similar publications to assist the DOE in attaining these goals. Such an effort would be useful to the NRC itself, since it will be responsible for evaluating the adequacy of designs submitted for licensing and since such submissions incorporate the precepts of human factors, systems safety, and systems engineering.

The DOE, the utilities, and their contractors should develop task analyses, preliminary hazard analyses, operating hazard analyses, software hazard analyses, maintenance hazard analyses, and so on to evaluate accurately the adequacy of a given design of equipment or systems that will be developed for the overall system. The NRC can provide policy statements, guidelines, and criteria documents to ensure that the detailed documentation from these disciplines will properly support decisions on transportation and waste management systems and equipment licensing.

B. Minimizing the Handling of Spent Fuel

The Board believes that technologies and system designs that minimize the handling of spent fuel, in addition to the development and implementation of the safety management procedures previously discussed, should be given priority. Some of the present concepts could involve the placement and replacement of fuel into canisters, casks, or containers several times from initial removal from the pool to final emplacement. The desirability of a goal to minimize handling becomes apparent when these potential multiple handlings are added to the expected increase in shipment volumes. Incidents of both human error and equipment malfunction can be expected to rise with increased frequency of handling. Where possible, repeated handling should be eliminated by system and equipment design.

C. Recommendations

The Board makes the following recommendations.

1. The NRC should develop policy statements, program guidelines, and, if feasible, criteria documents in human factors and system safety engineering that will help ensure that the DOE's and utilities' system acquisition programs address future accident potentials. The goal should be for the system acquisition programs to be complete in all the technologies that can contribute to operational safety and efficiency, including emergency and mitigation planning.

2. Priority should be placed on developing a high-level waste management system that minimizes the handling of spent fuel.

Section 4: Environment and Public Health

In its *First Report*, the Board identified several topics related to the maintenance of the environment and public health and safety that it believed required continued study. Two broad areas have received Board attention over the past seven months: (1) the Department of Energy's environmental protection program and (2) the regulations governing the potential effects of the repository on the environment and public health, most particularly, EPA Standard 40 CFR 191. The Board expressed concerns about three portions of the environmental program. Specific comments addressed the water resource, soil, and biologic studies contained in the program and the need for an ecosystem integration of these studies. The Board also noted the necessity for maintaining an adequate level of quality assurance in all studies. Several problems with 40 CFR 191 were noted, and it was recommended that changes in the regulation be sought while this EPA standard is being revised.

A. The Environmental Protection Program

Since the Board's *First Report*, members have participated in meetings, conferences, and technical exchanges that discussed the DOE's environmental program. Additionally, the Board has sought and obtained direct interaction with representatives of the State of Nevada and Native Americans on their concerns with that program. Board members also participated in a two-day field trip to the Nevada Test Site (NTS) and surrounding areas to visit testing, monitoring, archaeological, and natural resource sites. As a result of these activities, the Board has reached several conclusions.

Representatives of the State of Nevada said that they had two principal concerns with the environmental program. First, Nevada feels that detailed baseline data need to be developed to define the environmental and ecologic characteristics of the potential repository site; these studies should be completed *prior* to any disturbance from site characterization. Nevada's representatives do not believe that the DOE environmental assessment (DOE 1986) is adequate to characterize accurately the ecosystem baseline conditions that are essential to estimate the effects of site characterization. They claim that site-characterization studies, which include building roads, sinking shafts, driving tunnels, or performing surface-based testing, will significantly affect the site. The State also has indicated that it interprets the regulations to require that a baseline survey of the undisturbed site be performed before site characterization.

Second, state representatives and contractors believe that the implementation of their environmental programs is seriously restricted by funding limitations and lack of cooperation on the part of the DOE. Additionally, Nevada is reluctant to help DOE contractors perform areal studies because such cooperation might compromise the state's independent status.

The Board notes that the DOE has relied on the language of the Nuclear Waste Policy Act of 1982 and its amendments to justify foregoing integrated baseline studies in favor of a more modest environmental assessment. Nevada's position, however, that the site-characterization program is not environmentally benign or neutral to the indigenous ecosystem, appears reasonable. Since the DOE has concluded that the impact of site characterization will be negligible, the DOE needs to provide data to support its conclusion. Failing that, the Board concludes, the DOE should expand its baseline ecosystem studies so that the scale of the site-characterization impacts can be more fully evaluated.

The Native American representatives from the Western Shoshone National Council said the question of ownership of the NTS and surrounding lands is still before the courts. Consequently, it is the Native Americans' position that all activities at the Yucca Mountain Site are illegal. In the Council's view, the DOE needs to communicate more effectively with the Council on issues of mutual concern. Council representatives also believe that the DOE tends to focus solely on meeting the letter of the various federal regulations related to environmental and sociologic

matters, not listening to the concerns of the Native Americans.

The status of land ownership and the Native American tribes is a matter for legal adjudication and is beyond the scope of the Board's responsibilities. Although Native Americans do not appear to have made formal protests about underground nuclear detonations at the NTS in the area, their Council remains concerned about potential effects of the proposed repository at Yucca Mountain. Board members were unable to identify aspects of the site-characterization activities at the Yucca Mountain Site that would have substantial adverse effects on tribal interests; however, the Board believes that all reasonable steps should be taken to address the concerns of Native Americans.

The Board has learned that the DOE has a formal interactive organization, the Interface Control Working Group, which includes representatives of the DOE and its contractors and provides a structured procedure for interdisciplinary cooperation. The DOE noted its programmatic commitment to a rigorous quality assurance effort, but it was acknowledged that the resources allocated to the QA effort had not been identified and quantified. The DOE told Board members that the environmental impacts of site-characterization activities are expected to be small, but only the expected use of water was quantified.

The DOE's efforts in protecting endangered species and in cooperating with the U.S. Park and U.S. Fish and Wildlife services were described to members. The DOE acknowledged that its program on soil characterization and reclamation had not yet been initiated and that no plan had been developed to assess the effect on the Yucca Mountain ecosystem of a 2°C-increase in surface soil temperature from an operating repository.

The Board concludes that the DOE has made important strides in improving the coordination and integration of its environmental program and is continuing with these efforts. However, there is no systems approach to predicting how a desert shrub ecosystem, part of which is rooted in rock fracture systems and part in consolidated or unconsolidated alluvium, will respond to a rise in substrate temperature, a possible flux of $^{14}CO_2$ or tritium through fracture pathways, or alteration of groundwater flows and infiltration from site characterization. Also, the studies of soil and site reclamation need prompt attention and should be integrated into the task of understanding how the Yucca Mountain ecosystem will respond to the presence of the repository.

Finally, although in its *First Report* the Board stated that site-characterization activities are unlikely to create any significant risks to the involved ecosystem, the DOE has not quantified the possible impacts. The Board concludes that the impacts of site characterization should be quantified and compared, in approximate terms, to the effects of the repository's development and operation. Regardless of the results of this comparison, it would be helpful if the DOE and the State of Nevada would explore the option of negotiating a mutually acceptable joint environmental study to reduce the costs and minimize delays caused by possible adversarial treatments of duplicate studies. In any case, all field tests and/or experiments funded by the Nuclear Waste Fund, regardless of who performs them, should be subject to peer review and be designed to produce data appropriate for use during licensing.

B. Protection Standards and Regulations

In its discussion with the Board, the DOE indicated that it has proposed limits on radiation exposures to workers and members of the public that are the same as, or equivalent to, those required by the EPA and the NRC. The limits generally are consistent with the guidance of the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection and are contained in DOE Orders 5400.5 and 5480.11.

In March 1990, Board members presented their concerns about EPA Standard 40 CFR 191 to the NRC's Advisory Committee on Nuclear Waste. The Board has considered a report on the regulatory structure in the United States recently issued by the National Research Council Board on Radioactive Waste Management, "Rethinking High-Level Radioactive Waste Disposal" (National Research Council 1990). This report is discussed in more detail in Chapter 3. Following the issuance of that report, a symposium was

held in September 1990 by the Board on Radioactive Waste Management, at which the NWTRB was invited to make a presentation on the EPA Standards. Drs. Don. U. Deere, Board chairman, and Melvin W. Carter, chair of the Environment & Public Health Panel, made the presentation on behalf of the Board.*

C. Recommendations

The Board makes the following recommendations.

1. The DOE should continue to include in its study plans the interests and concerns of Native Americans, the states of California and Nevada, the National Park Service, the Soil Conservation Service, and the Fish and Wildlife Service.

2. The DOE and the State of Nevada should explore the possibility of initiating a cooperative program to develop baseline environmental information.

3. All environmental programs at the Yucca Mountain Site funded by the Nuclear Waste Fund should be developed and conducted in a manner that the data obtained are appropriate to and can be used during licensing.

4. An integrated environmental program that takes cognizance of ecosystem processes should be developed for the Yucca Mountain Site. The results of this program should permit assessment of the effects of site characterization and repository construction and operation on the local ecosystem. The program also should provide a basis for understanding ecologic pathways for any radioactive materials that might escape containment during repository construction, operation, and decommissioning.

* The Board has since suggested in letters to the EPA and the NRC that the two agencies enter into negotiated rulemaking on 40 CFR 191 and 10 CFR 60.

Section 5: Risk and Performance Analysis

In its *First Report*, the Board described three areas of concern relating to risk and performance analysis: (1) performance allocation, specifically, the need for a flexible strategy for obtaining information in the site-characterization process to support performance assessment, (2) methodology for assessing expert judgment, and (3) overall characterization of the risk posed by a repository at the Yucca Mountain Site. The Board made specific recommendations urging that the DOE develop a methodology for performance assessment and begin using performance assessment in support of decisions on the Yucca Mountain site-characterization process. In addition, because of its integrative character, the cross-cutting issues for further inquiry discussed in Chapter 3 of the *First Report* are related directly or indirectly to risk and performance assessment.

Partially in response to the Board's concerns and recommendations, the DOE has established four task forces to consider programmatic decisions relating to site-characterization activities and license application strategy. These task forces are addressing (1) alternative licensing strategies, (2) surface-based testing prioritization, (3) Calico Hills risk/benefit analysis, and (4) evaluation of alternatives for the exploratory shaft facility. The DOE has presented briefings at Board meetings on the status of the four task force studies. Only for the Calico Hills risk/benefit analysis have preliminary overall conclusions been presented, and these conclusions are not yet supported with documentation. Most of the work of the four task forces is scheduled for completion by the end of 1990, with documentation to be completed in early 1991.

Although no Board meeting in the past seven months was devoted solely to risk and performance analysis, such analysis played an integral role in discussions related to the four DOE task force activities and in other Board activities, including during the Board's visit in June to Sweden and the Federal Republic of Germany.

In July 1990, the National Research Council Board on Radioactive Waste Management released a report entitled "Rethinking High-Level Radioactive Waste Disposal" (National Research Council 1990). The report contains numerous findings and conclusions that relate to risk and performance analysis. (See Chapter 3 for a brief discussion of this report.) Following is a discussion of three risk and performance issues: (1) the DOE task force studies, (2) assessment of expert judgment, and (3) use of natural analogues. The discussion is based on insights gained through recent Board activities.

A. DOE Task Force Studies

The DOE task force studies respond to the Board's recommendations that the DOE develop a methodology for performance assessment and use performance assessment (and more broadly, systems engineering and analysis) to support the coordination, integration, and control of the site-characterization process. The studies improve the Board's and other interested parties' understanding of the basis for the DOE's strategy for surface and underground activities in site characterization. They should help the DOE to identify factors that could cause the site to be disqualified and to develop strategies to reduce uncertainties on these critical factors by gathering the appropriate scientific data as early as possible in the site-characterization process.

Three of the task force studies use decision-analysis techniques to describe uncertainties explicitly and to calculate the value of reducing or resolving uncertainties. As noted in the National Research Council report,

> *Many of the uncertainties associated with a candidate repository site will be technically interesting but irrelevant to overall repository performance. Further, the issues that are analytically tractable are not necessarily the most important. The key task for performance modeling is to separate the significant uncertainties and risks from the trivial (National Research Council 1990, 4).*

Such separation of the significant from the trivial is extremely difficult if the basis for management is the DOE's 6,300-page Site Characterization Plan (DOE 1988). The task force studies appear to have chosen the appropriate methodology—decision analysis and sensitivity analysis—for accomplishing this needed separation and establishing appropriate priorities for site-characterization activities.

The first Board report contained a recommendation that the DOE explore the Calico Hills unit (tuff), which provides a critical barrier to the migration of radionuclides from the repository horizon to the water table below. (See Figure 2-1.) The Calico Hills Risk/Benefit Analysis Task Force is evaluating the alternatives of exploring the Calico Hills unit with surface borings and examination of surface outcrops, with limited drifting as part of the exploratory shaft facility, and with extensive drifting that would permit direct examination of faults and other significant geologic features in the Calico Hills unit.

Preliminary results from the DOE's risk/benefit analysis indicate that constructing extensive drifts in the Calico Hills unit would have little potential effect on repository performance, therefore not posing a problem in the licensing process, and that the knowledge gained would be effective in resolving uncertainties about the flow regime. Furthermore, the study also concluded that the overall risk posed by the repository is so small that the existence or nonexistence of this knowledge is not likely to affect the ability of the repository to pass the EPA performance standards by a wide margin. Despite the low "value" of this additional information with respect to site acceptability, the DOE Calico Hills Risk/Benefit Analysis Task Force recommended that extensive drifting in the Calico Hills be carried out to improve the understanding of site conditions and to gain confidence in performance predictions. The Board has not had the opportunity to review the technical information on which these analytical results are based. It deserves careful review.

The task forces on the Surface-Based Testing Prioritization and the Exploratory Shaft Facility Alternatives Evaluation are expected to complete their analyses this fall. When the full results and supporting documentation become available, they also will deserve careful review by the Board and other interested parties.

B. Assessment of Expert Judgment

The methodology used in the task force studies relies extensively on the professional judgment of technical experts. Given the absence of either data or a well-validated theory for predicting many critical aspects of repository performance and the necessity for decisions on the repository program, it is essential that the DOE make use of such judgments. The Board is encouraged that the DOE is using formal methods for assessing expert judgment about uncertainty in the task force studies and looks forward to reviewing the methodology and examples of its use when the studies are further advanced.

The Board is concerned, however, that the DOE has relied almost entirely on its own scientific experts and contractors. National Research Council reviews of the DOE program have repeatedly urged the agency to solicit the judgment of experts *outside* its program and to document carefully the basis for the judgments. In a letter to the OCRWM director dated April 10, 1986, the Board on Radioactive Waste Management reported that the "DOE did not take the [National Research Council] Board's advice, offered twice in writing, to involve outside groups of experts in the site-ranking process" (National Research Council 1986). The July 1990 National Research Council report states that "setting forth the reasoning of DOE staff and of independent outside experts contributes to learning and builds credibility in the process even when the experts disagree with DOE staff and among themselves" (National Research Council 1990, 24).

The Board believes that it is important for the DOE to open the way for a broad review within the technical community of the critical judgments underlying the assessment of performance and risk for a repository at the Yucca Mountain Site. The current task force studies provide an excellent opportunity for such outside technical review.

C. Use of Natural Analogues

Because of the difficulties in modeling the transport of radionuclides through a complex geologic system, approaches to performance assessment based on modeling alone may be quantitatively inconclusive. Natural analogues are those naturally occurring geologic settings that can provide information on aspects of repository performance. Most often they involve bodies of uranium ore or other radioactive materials on which environmental forces have acted over long periods of time, and the extent of radionuclide transport can be inferred from measurements.

Underground nuclear weapons tests at the Nevada Test Site provide an instance where plutonium, other transuranic isotopes, and fission products have been introduced into geologic strata. While the time periods are decades rather than millions of years, the tests allow opportunities to observe migration over time in geologic, hydrologic, and ecologic settings close to those at the Yucca Mountain Site. Performance assessment strategies in the nuclear repository programs of many other countries include investigating the use of analogues. The recent National Research Council report recommends both analogues and professional judgment as supplements to modeling (National Research Council 1990, 27-28). The Board concurs with this recommendation.

D. Recommendations

The Board makes the following three recommendations:

1. The DOE should continue using decision-aiding methodology to provide more explicit and formal means for relating program decisions to risk and performance issues. Such methods should be used in an iterative and ongoing fashion to explain the reasoning behind major programmatic decisions before these decisions are committed. The four existing DOE task force studies applying these methods should be closely coordinated.

2. The DOE should continue to develop methods for assessing expert judgment in areas of significant uncertainty. Furthermore, the DOE should incorporate into the current task force studies the views of technical experts *outside* the DOE and its contractors. The basis for each expert judgment needs to be carefully documented.

3. The DOE should consider investigating more extensively the use of natural analogues to support performance assessment for a potential repository at the Yucca Mountain Site.

Chapter 3
Concluding Perspectives

The Board recognizes recent progress and some positive developments in the DOE's program for the permanent disposal of the nation's civilian high-level radioactive waste. This progress started with the Secretary of Energy's November 1989 comprehensive report to the Congress (DOE 1989) redirecting the program, and continued with the appointment of Dr. John W. Bartlett to fill the two-and-a-half-year vacancy of OCRWM director. Most recently, the DOE developed and implemented a new management plan that creates more direct program relationships and accountability.

Since July 31, a number of developments have taken place that go beyond the scope of this report, but on which the Board wishes to comment. They include the decision of the Ninth U.S. Circuit Court on the litigation brought by the State of Nevada against the DOE, efforts to revise standards and regulations, the publication of a National Research Council report on the U.S. high-level waste repository program, the development of a licensing support system, and the appointment of a nuclear waste negotiator. This chapter discusses the DOE's progress, these related developments, and the Board's future activities.

A. DOE Progress

On April 5, 1990, Dr. John Bartlett was appointed director of the DOE's Office of Civilian Radioactive Waste Management. One month later, he announced the development of an improved management plan, to be in place by August 1, 1990.

This internal reorganization is aimed at providing clear lines of responsibility, authority, and accountability for the DOE program and its contractors. The reorganization is viewed as being consistent with an overall strategy (DOE 1990, OCRWM) that recognizes that programmatic and management functions, as well as facilities and equipment, are necessary for the implementation of a high-level waste repository. The reorganization moves away from the matrix organization used over the past two years. It enhances the role of the Yucca Mountain Project Office (YMPO, the group located in Nevada, which is responsible for the scientific investigations that will determine the suitability of Yucca Mountain Site), allowing it to report directly to the OCRWM director instead of through an intermediary in the Washington headquarters.

In the past, the Board received many informal comments about the problems associated with managing the high-level waste program. Different and sometimes competing national laboratories comprised of many individual scientists and engineers appeared to be working on a vast array of projects, not all of which were relevant to the problems at hand. Within OCRWM, apparently parallel and sometimes rival efforts were undertaken by the YMPO and headquarters' groups. The Board is looking forward to the implementation of the long-delayed management and operating contractor, who will be responsible for designing and analyzing the high-level waste management system to ensure that it is optimized and that the interfaces among all program elements are clearly defined and controlled.

The Board, in its relatively brief 19-month tenure, has been able to familiarize itself with many aspects of the DOE's high-level waste program. DOE staff and representatives have been responsive to the Board in providing requested information, organizing meetings, and addressing Board concerns. Pres-

entations to the Board and its panels by the DOE and its contractors on the exploratory shaft facility alternatives analysis, the risk/benefit analysis studies of the Calico Hills nonwelded tuff, and the prioritization of surface-based testing exemplify the activities undertaken to address some of the issues previously identified by the Board and others. The Board is generally pleased with the DOE's effort to respond to many of the recommendations the Board made in its *First Report*. (The DOE responses to Board recommendations can be found in Appendix E.) Indeed, these responses represent good-faith attempts on the part of the DOE to address various problem areas. However, the ultimate results of these activities can be judged accurately only over time. As the DOE's program progresses, the Board will continue to fulfill its mandated monitoring responsibilities and to report its findings and recommendations to Congress and the Secretary of Energy.

B. Related Developments

The impasse with the State of Nevada

One of the Board's ongoing concerns is the continuing impasse with the State of Nevada over access to the Yucca Mountain Site. On August 16, 1990, the U.S. Court of Appeals for the Ninth Circuit heard oral arguments in litigation brought in January 1990 by the State of Nevada against the U.S. Department of Energy seeking the termination of activities involving the Yucca Mountain Site, Nevada (*Nevada v. Watkins*, Case No. 90-70004). In this case, Nevada contended that it submitted an effective notice of disapproval of the site to Congress, which Congress failed to override in the manner set forth in the NWPA. The state also contended that the DOE should have ceased activities at the site on the basis of various geologic and other conditions that should have disqualified the site from further consideration.

The federal government countered that the state's purported "veto" action was premature, contested the state's assertions concerning known conditions at the site, and argued that detailed studies that would address those assertions have been delayed because of the state's failure to grant to the DOE various environmental and other necessary permits. The failure of Nevada to grant those permits is the subject of separate litigation brought by the federal government in the U.S. District Court of Nevada (*United States v. Nevada, et al.*, Case No. CV-S-90-65). Proceedings in that district court case were stayed pending the outcome of the latter case.

On September 19, 1990, the Ninth Circuit Court issued a decision in favor of the DOE. Despite this decision, Nevada may seek a further stay in proceedings at the district court while it seeks a Supreme Court review of the Ninth Circuit decision. This will undoubtedly continue to delay the DOE's progress to characterize the Yucca Mountain Site.

The Board sees progress and new commitment by the DOE with its new management strategies to carry forward its mandated responsibilities in investigating the suitability of Yucca Mountain Site for a high-level repository. Its progress, however, will depend directly on receiving the necessary permits to allow site access to carry out testing. The suitability of the Yucca Mountain Site cannot be fully evaluated until additional surface and underground site characterization has been completed.

Regulatory framework

Many scientists in the technical community are concerned about the nation's ability to construct and license a repository in accordance with current federal standards and regulations. These standards and regulations have been criticized, and many groups have broad concerns about the present regulatory framework.

On January 1, 1990, the Environmental Protection Agency placed in the docket of the remanded EPA Standard 40 CFR 191 a second working draft of the standard. This draft summarized the EPA's proposed approach in revising the standard. In March, the EPA staff presented its rationale for the proposed changes in the standard to the Advisory Committee on Nuclear Waste (ACNW). As previously mentioned, Board members addressed the ACNW at that time on their concerns with the standard, including the second draft. This standard also was considered in the National Research Council's Board on Radioactive Waste Management report (see below) and was a topic of lengthy discussion at a two-day sym-

posium in September hosted by the National Research Council. Drs. Don U. Deere, Board chairman, and Melvin W. Carter, chair of the Environment & Public Health Panel were invited to present the Board's view of the standards.

The Nuclear Regulatory Commission's principal regulation for the disposal of high-level radioactive waste is 10 CFR 60. This regulation provides both qualitative and quantitative directions to the DOE in developing, designing, and operating a repository. Certain specific criteria have been subjected to external criticism as being, on one hand, too prescriptive and, on the other, ambiguous and ill-defined. One point that lacked clarity, as indicated in the Board's *First Report*, was the requirement that the waste package provide substantially complete containment of the waste for 300 to 1,000 years. This requirement was interpreted by the DOE as limiting the allowable lifetime of the waste package to 1,000 years. To clarify the requirement's intent, the NRC issued a staff position on July 27, 1990 (NRC 1990). This statement provides a detailed history of the development of the requirement and clearly points out that the *minimum* performance must be between 300 and 1,000 years. It further states that the DOE may propose and take credit for waste package lifetimes exceeding 1,000 years.

The Board believes that the current regulatory framework can be improved. With such improvements, a candidate site, judged to be technically suitable, also can be licensed. In recent letters to William Reilly, EPA administrator, and Kenneth Carr, NRC chair, the Board has suggested that the two agencies enter into negotiated rulemaking on 40 CFR 191 and 10 CFR 60.

The National Research Council, Board on Radioactive Waste Management report*

In July 1990, the National Research Council, principal operating agency for the National Academy of Sciences, issued a report entitled "Rethinking High-Level Radioactive Waste Disposal" (National Research Council 1990). This report is the result of a July 1988 retreat that was attended by about three dozen physical scientists, engineers, political scientists, and other experts familiar with issues related to radioactive waste disposal. Invited guests at the retreat also included representatives from the Board, the DOE, NRC, and the EPA.

In summary, the report states that there is no scientific or technical reason why a satisfactory geologic repository cannot be built for the disposal of spent fuel and high-level radioactive waste. However, the public is very concerned about the long-term safety of radioactive waste disposal, especially in light of current technical and institutional uncertainties. The federal government's program for the disposal of high-level radioactive waste has addressed these concerns and uncertainties by adopting well-defined and conservative goals and standards; using complex computer models to generate apparently precise, numeric predictions of long-term repository performance; and specifying overly optimistic program development schedules.

According to this report, the U.S. program, as implemented over the past decade, is unlikely to succeed. As more and better information is collected, today's goals, standards, and schedules will probably have to be modified. Such changes may produce delays, frustration, and a loss of public confidence. To avoid such a situation, the report advocates an approach that is less prescriptive and more accommodating to new insights, unexpected information, and changing circumstances. The report's authors believe that implementing this more flexible approach will require significant changes in laws, regulations, and program management.

Although some of the conclusions in the National Research Council's report are consistent with the views that have been expressed in the first two Board reports and comments made by members at various Board meetings, some are based on 1988

* The National Research Council is the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities.

conditions and do not take into account recent positive changes that have occurred in the DOE's civilian nuclear waste program.

Licensing support system

The NRC evaluates and licenses all commercial facilities that handle radioactive materials (e.g., all nuclear power plants). During licensing, all interested parties (state and local agencies, environmental groups, and individuals) are guaranteed the right to participate and are allowed access to any and all documents relating to a facility's licensing.

It is estimated that licensing a final repository in any location may mean making as many as 25 million pages of information available to interested parties. Typically, licensing a nuclear power plant, which may involve the review of 10,000 pages, can be completed in 12 to 18 months. The NWPA stipulated that the NRC must complete the repository license review in three years. Therefore, the manual procedures used in licensing nuclear power plants will be replaced by a licensing support system (LSS) for the repository.

The LSS is a computerized storage and retrieval system that will make all relevant documents available before the repository licensing hearings. Plans call for the system to work much like commercially available databases but on a much larger scale. While its main purpose is to support the license application review, the support system will allow for an early technical review of materials concerning repository siting and construction.

Authority for the LSS comes from a negotiated rulemaking process that ended in April 1989 (10 CFR 2 subpart J). This rule sets forth the agreed-upon standards and procedures for LSS implementation and assigns design responsibility to the DOE. Independent control of the system is assigned to the NRC Office of the LSS Administrator. In addition, the rule established an advisory review panel to represent many of the interested parties that may use the LSS.

Cost estimates to set up the LSS range from $192 million to $236 million (in 1988 dollars). The LSS is to be developed and paid for by the DOE, but operated by the NRC. This dual involvement resulted for a while in significant differences of opinion between the two agencies about when and how the system should be implemented. These differences have since been resolved, and a pilot-scale version of the LSS is scheduled to be ready for testing and evaluation in 1993.

As a key agency involved with nuclear waste disposal, the NWTRB expects to become a full participant in the LSS. This means that all of the Board's materials that meet the criteria established by the DOE will be entered into the LSS and can be accessed by anyone.

The appointment of a nuclear waste negotiator

The Board welcomes the confirmation in July 1990 of David H. Leroy, former lieutenant governor of Idaho, to the position of nuclear waste negotiator. It will be his responsibility to work with governors, Native Americans, and others in an effort to find a willing host state for a monitored retrievable storage facility for high-level radioactive waste and possibly for a repository itself.

C. The Board's Future Plans

In Chapter 2 of this report, the Board made a number of recommendations that it hopes will facilitate further progress in the DOE's waste management program. As part of its ongoing work, the Board has scheduled a number of activities for the next six-month period, August 1, 1990, to January 31, 1991. (See Appendix C.)

In August 1990, the Board held the first of a number of public hearings it has scheduled for the coming months. The Board is interested in hearing the views of the public and other parties in areas where there is interest in the progress of the nation's program for the management of civilian nuclear waste. The August hearing, which took place in Amargosa Valley, Nye County (the county in which Yucca Mountain Site is located), primarily addressed transportation-related issues. In October, a hearing in Reno, Nevada, solicited public comment on issues relating to the potential environmental and public health effects of characterizing, constructing, and op-

erating a repository. A second public hearing on transportation issues will be held in November in Reno, Nevada.

In addition to public hearings, panel meetings have been scheduled for October on the prioritization of surface-based testing; socioeconomic issues relating to characterizing, constructing, and operating a repository; and transportation issues. Meetings on quality assurance and transportation issues are set for November. During the coming year, the Board plans to address a number of issues. Some of these issues include the recommended repository design and the thermal constraints used in the design, testing priorities to determine early site suitability, and the concepts and technology proposed for sealing boreholes and shafts.

On October 2, 1990, Dr. Don U. Deere, chairman of the Board, had the honor of testifying before the Subcommittee on Nuclear Regulation of the Committee on Environment and Public Works in the U.S. Senate. In addition to responding to subcommittee members' questions, Dr. Deere's testimony focused on three specific topics: (1) the technical aspects of maximizing the isolation of the waste, (2) regulatory improvements, and (3) nontechnical siting problems, plus a brief evaluation of the DOE's current program. The main points of the Board's testimony are summarized in Figure 3-1.

As a result of its trip to Sweden, the Board and the Swedish National Board for Spent Nuclear Fuel (SKN), which have similar assignments in their respective countries' high-level radioactive waste programs, are developing closer ties. The Board and the SKN are in the process of establishing a bilateral agreement to exchange technical information and cooperate on matters concerning high-level waste management. Some topics of mutual interest include radioactive waste and spent fuel research, the role and function of engineered and geologic barriers, models and their validation, and social science issues.

The Board plans to continue gathering information on foreign waste disposal programs by traveling to Canada in the spring of 1991. The Board is in the process of approaching the appropriate Canadian authorities to explore the possibility of meeting with technical experts to learn more about the status of Canada's program, including plans for interim storage of spent nuclear fuel, and the process used for developing disposal technologies and evaluating potential disposal sites.

Figure 3-1

Testimony before the Subcommittee on Nuclear Regulation Committee on Environment and Public Works United States Senate, October 2, 1990

There is currently a worldwide scientific consensus that a deep geologic repository is the best option for the disposal of high-level waste. The Board believes that there are no insurmountable technical reasons why an acceptable deep geologic repository cannot be developed.

1. Maximizing waste isolation

The overall confidence in a repository's long-term performance is enhanced by using engineered barriers in addition to geologic barriers. Improved engineered barriers designed for more than 1,000 years can, in the Board's judgment, make a substantial contribution to waste isolation and increase the nation's overall confidence in the ability of the repository to meet its performance goals.

2. Regulatory improvements

The Board believes that the regulatory framework should be sufficiently conservative to fully protect public health and the environment. It should, however, not be so restrictive as to foreclose at the outset the use of repository sites that can be shown to be suitable on the basis of sound scientific and technical considerations. Present federal standards and regulations have been criticized as being too stringent and prescriptive, others as too ambiguous or simply inappropriate for geologic repositories. The Board detailed several concerns about the EPA Standard 40 CFR 191 in its *First Report to the U.S. Congress and the U.S. Secretary of Energy*. The NWTRB believes that the current regulatory framework can be improved. With such improvements, a candidate site, judged to be technically suitable, can also be licensed.

3. Nontechnical siting problems

Site characterization is an essential phase in determining the suitability of the candidate site for repository development. Any delays in site characterization will result in comparable delays in determining site suitability. The DOE's efforts to characterize the Yucca Mountain Site are presently constrained by the State of Nevada's refusal to issue the necessary permits.